Naval Research Laboratory
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Monthly Mean Sea Ice Data from the Polar Ice Prediction System, the Regional Polar Ice Prediction System – Barents Sea and the Regional Polar Ice Prediction System – Greenland Sea

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Oceanography Division

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The Polar Ice Prediction System (PIPS), the Regional Polar Ice Prediction System – Barents (RPIPS-B) and the Regional Polar Ice Prediction System – Greenland Sea (RPIPS-G) are all operational sea ice forecasting systems that have been run daily at the Fleet Numerical Meteorology and Oceanography Center (FNMOC) since September 1987, June 1989, and October 1991, respectively. The basis for all three models is the Hibler ice model (Hibler, W. D. (1979). A Dynamic Thermodynamic Sea Ice Model. *Journal of Physical Oceanography* 9:815-846; Hibler, W. D. (1980). Modeling a Variable Thickness Sea Ice Cover. *Monthly Weather Review* 108:1944-1973). The ice models are driven by monthly mean ocean currents and deep ocean heat fluxes derived from the Hibler and Bryan (A Diagnostic Ice-Ocean Model. *Journal of Physical Oceanography* 17:987-1015 (1987) coupled ice-ocean model. They are also driven by atmospheric forcing from the Navy Operational Global Atmospheric Prediction System (NOGAPS) (Rosmond, T. E. (1981). NOGAPS: Navy Operational Global Atmospheric Prediction System. In Fifth Conference on Numerical Weather Prediction (Monterey, California), American Meteorological Society, Boston, Massachusetts, preprint volume, 74-79; Hogan et al. (1990). The Description of the Navy Operational Global Atmospheric Prediction System's Forecast Model. Naval Research Laboratory, Monterey, California, NOARL Report 13). Each day a 24-h forecast of PIPS, RPIPS-B, and RPIPS-G is submitted and archived by the Naval Research Laboratory. This memorandum report contains monthly mean values of geostrophic winds, ice drift, ice thickness, and ice concentration from the PIPS, RPIPS-B, and RPIPS-G 24-h forecasts from 1993.

14. Subject Terms.
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MONTHLY MEAN SEA ICE DATA FROM THE POLAR ICE PREDICTION SYSTEM (PIPS), THE REGIONAL POLAR ICE PREDICTION SYSTEM - BARENTS (RPIPS-B) AND THE REGIONAL POLAR ICE PREDICTION SYSTEM - GREENLAND SEA (RPIPS-G)

The Polar Ice Prediction System (PIPS), the Regional Polar Ice Prediction System - Barents Sea (RPIPS-B) and the Regional Polar Ice Prediction System - Greenland Sea (RPIPS-G) are all operational sea ice forecasting systems that have been run daily at the Fleet Numerical Meteorology and Oceanography Center (FNMOC) since September 1987, June 1989, and October 1991, respectively. The basis for all three models is the Hibler ice model (Hibler 1979; 1980). The Hibler ice model calculates ice drift, ice thickness, ice concentration (ice edge), and the growth/decay of ice based on both dynamic and thermodynamic effects. The ice models are driven by monthly mean ocean currents and deep ocean heat fluxes derived from the Hibler and Bryan (1987) coupled ice-ocean model. They are also driven by atmospheric forcing from the Navy Operational Global Atmospheric Prediction System (NOGAPS) (Rosmond 1981; Hogan et al. 1990).

PIPS forecasts over the entire Arctic basin, the Barents Sea, and the Greenland/Norwegian Sea using a grid resolution of 127 km (Fig. 1). RPIPS-B, a higher resolution version of PIPS, forecasts over the Barents Sea and the western part of the Kara Sea using a grid resolution of 25 km (Fig. 2). RPIPS-G, another higher resolution version of PIPS, forecasts over the region adjacent to the East Greenland coast using a grid resolution of 20 km (Fig. 3). The time step used by all three ice models is 6 h. The length of the daily operational PIPS, RPIPS-B, and RPIPS-G forecast, 120 h, is based on the length of the NOGAPS forecast. Each model is restarted daily using its own 24 h forecast. Once per week, the PIPS, RPIPS-B, and RPIPS-G ice concentration is initialized (updated) by the digitized hand analysis of ice concentration from the Navy/National Oceanic and Atmospheric Administration (NOAA) National Ice Center (NIC) [formerly the Joint Ice Center]. If these restart fields are not available, then each model initializes from a model derived climatology. To create these climatological databases, each model was run for 3 years, using 1986 NOGAPS forcing for each year until a "cyclic" equilibrium was reached. A detailed description of PIPS may be found in Preller and Posey (1989a) and Preller (1985). A detailed description of PIPS-B may be found in Preller et al. (1989). A preliminary study of RPIPS-G may be found in Preller et al. (1990).

The following report, the fifth in a series (Preller and Posey 1989c; Posey and Preller 1990; Posey and Preller 1991; Posey and Preller 1993), contains monthly mean values of geostrophic wind, ice drift, ice thickness, and ice concentration derived from PIPS, RPIPS-B, and RPIPS-G 24 h forecast from January to December 1993.

The scale factor for the geostrophic wind velocities, located in the lower right-hand corner of each figure, is 20 m/s for the PIPS results, 30 m/s for the RPIPS-B and RPIPS-G results. The scale factor for all the model's ice drift velocities, located in the lower right-hand corner, is 30 cm/s. RPIPS-B ice drift values are plotted at every other point, RPIPS-G at every 4th point, and PIPS at every point. The ice thickness contours for PIPS begin at 0.5 m and are incremented by 0.5 m. The ice thickness contours for RPIPS-B begin at 0.1 m and are incremented by 0.1 m. The ice thickness contours for RPIPS-G have two contour intervals, the first begins at 0.1 m and incremented by 0.1 m until the 0.4 m is reached; the second begins at 0.5 m and is incremented by 0.5 m. The ice concentration contours for PIPS and RPIPS-G begin at 0.2 (20%) and are incremented by 0.05 (5%). For the RPIPS-B ice concentration results, the contours begin at 0.2 (20%) and are incremented by 0.1 (10%).

SPECIFIC COMMENTS ON EACH YEAR

PIPS 1993 RESULTS

The PIPS 1993 results, a continuation of our last report, begins with January 1993. The 1993 PIPS monthly means were calculated from the 24 h forecasts. Each day a 24h PIPS forecast was submitted by the Naval Research Laboratory (NRL) to run on the FNMOC Cyber 205. The output from this forecast was brought back to NRL and archived. In the past several years, PIPS has often forecasted excessive ice growth in the marginal ice zones during the winter season. During 1990, both corrections to NOGAPS and the ice model code resulted in more realistic ice concentrations and ice thickness in the PIPS forecasts. Also during this period, NIC, with the assistance of FNMOC, incorporated a more fully automated technique of transmitting and quality controlling the ice concentration update to FNMOC. As a direct result, the PIPS model's ice concentration was updated 46 out of 52 weeks.

During July 1991, PIPS was upgraded to use the high resolution wind stresses, a new product produced from the NOGAPS model, in order to predict a more accurate ice drift. In order to remain consistent with the previous reports, we have plotted the geostrophic wind calculated from the NOGAPS surface pressures even though the NOGAPS surface stresses were used to calculate the ice drift.

Geostrophic winds and the resultant PIPS ice drift show the Arctic to be dominated by a clockwise circulation in the Beaufort and Chukchi Sea regions for most of the year. This pattern begins to decay and reverses to a counter clockwise circulation in the summer. This reversal of the dominant anticyclonic gyre, usually occurring in August or September, appears to be due to an increase in the number of low pressure systems in this region during the late summer (Preller and Posey 1989b). A return to normal clockwise circulation usually begins in October. During 1993 the typical pattern appeared, the reversal occurred during the month of August. Then the ice motion slowly reverted back to a clockwise circulation in the Beaufort and Chukchi Sea regions during December, a few months later than observed in previous years. As seen in previous years, the "Odden," a formation of very thin ice that protrudes east of the Greenland coast, appeared from February to April.

RPIPS-B 1993 RESULTS

RPIPS-B was designed, at higher resolution than PIPS, in order to predict a more accurate location of the ice edge, to obtain better resolution of straits, and to better define land and island boundaries. Similar to PIPS, the RPIPS-B results are a continuation from our previous report. Along with PIPS, each day a 24 h RPIPS-B forecast was submitted by NRL to run on the FNMOC computer. The output from this forecast was brought back and archived at NRL. All of the RPIPS-B results shown were calculated from the 24 h forecast field. Similar to PIPS, RPIPS-B was updated each week with ice concentration data from NIC.

In May of 1991, RPIPS-B was upgraded to use the high resolution surface stresses from the NOGAPS model. As with the PIPS results, the RPIPS-B ice drift results were improved by using the higher resolution stresses.

As in the PIPS results, RPIPS-B compared well with observed ice concentrations as a direct result of the regular weekly updating of the ice concentration (46 out of 52 weeks).

RPIPS-G 1993 RESULTS

RPIPS-G was designed, also at higher resolution than PIPS, in order to predict a more accurate location of the ice edge to obtain better resolution of the Fram Strait and to better define land and island boundaries. Along with PIPS and RPIPS-B, each day a 24 h RPIPS-G forecast was submitted by NRL to run on the FNMOC computer. The output from this forecast is brought back and archived. All of the RPIPS-G results were calculated from the 24 h forecast field. Similar to both PIPS and RPIPS-B, RPIPS-G is updated each week with ice concentration data from NIC. This includes a correction to the thickness field as well. If the data indicated that no ice actually existed in a grid cell that contained ice, then the ice was removed and heat was added to the mixed layer to keep ice from immediately growing back. If the data indicated that ice actually existed in a grid cell that contained only open water, then ice was added to the cell according to the following equation:

If $A \geq 0.5$ then $H = 0.4$ m
If $A < 0.5$ then $H = 0.2$ m

where A is the ice concentration (0.5 = 50%) and H is the ice thickness.

As seen in the PIPS model, the Odden appeared in RPIPS-G but with greater detail than PIPS. The feature started to occur in February and then slowly disappeared by April.

As in the PIPS and RPIPS-B results, RPIPS-G compared well with observed ice concentrations as a direct result of the regular weekly updating of the ice concentration (46 out of 52 weeks).

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PIPS MODEL GRID

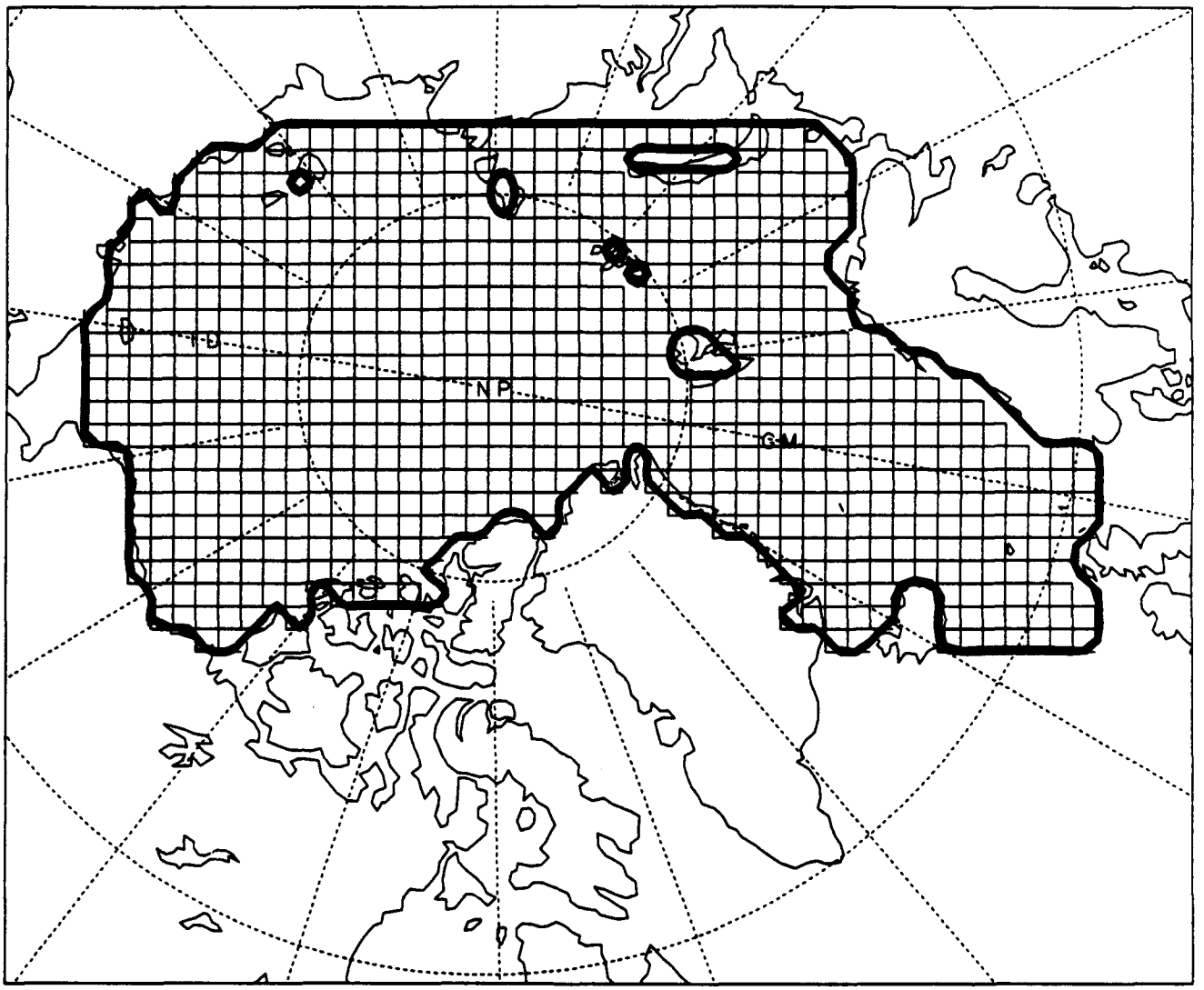

Figure 1. PIPS domain with the 127-km resolution grid overlaid.

PIPS 1993

MONTHLY MEANS

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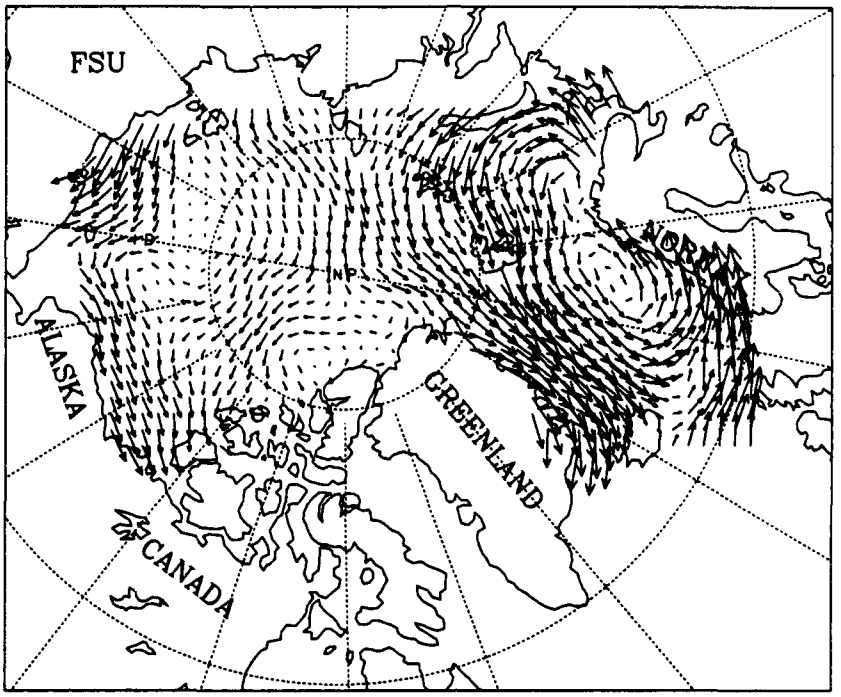

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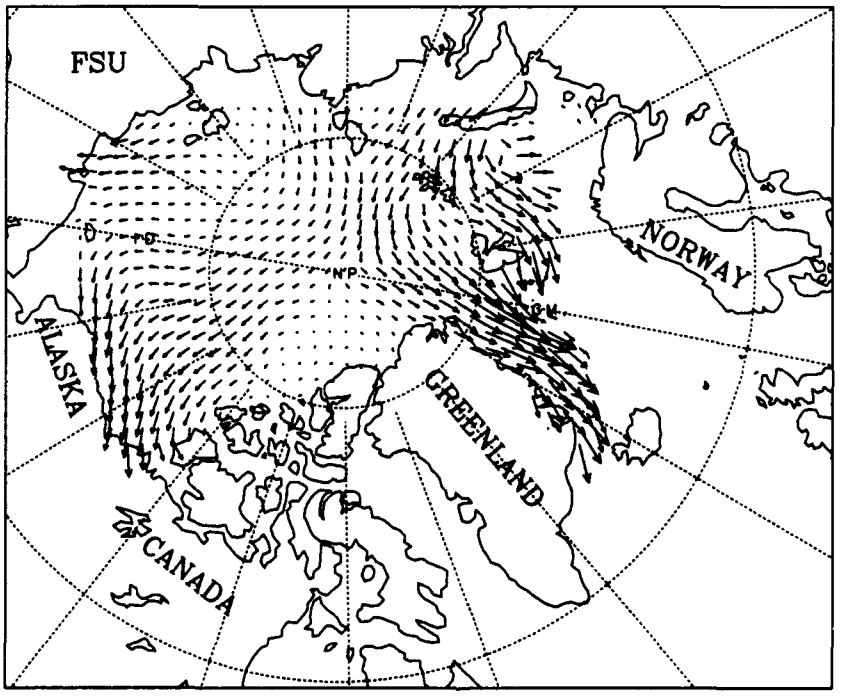

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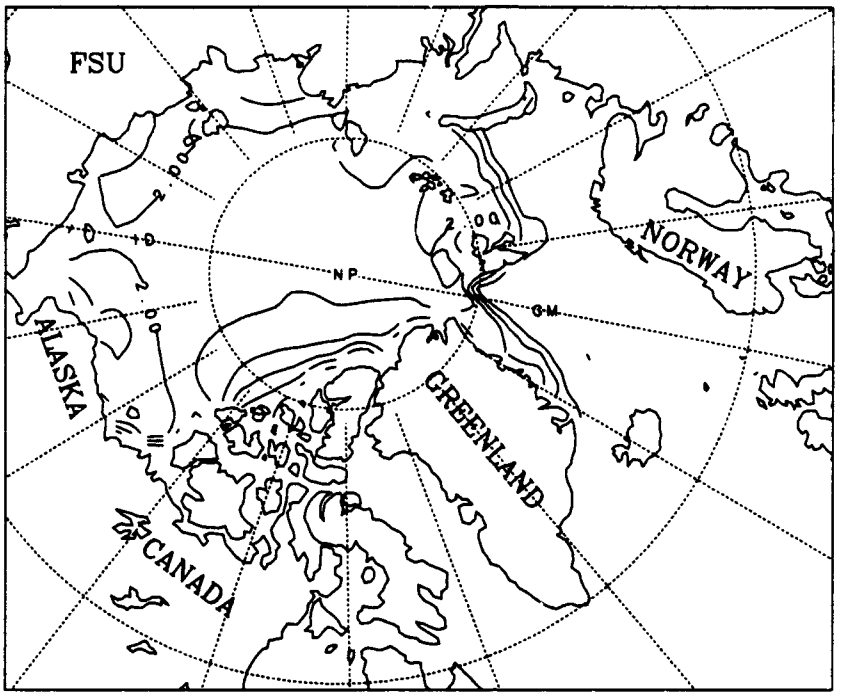

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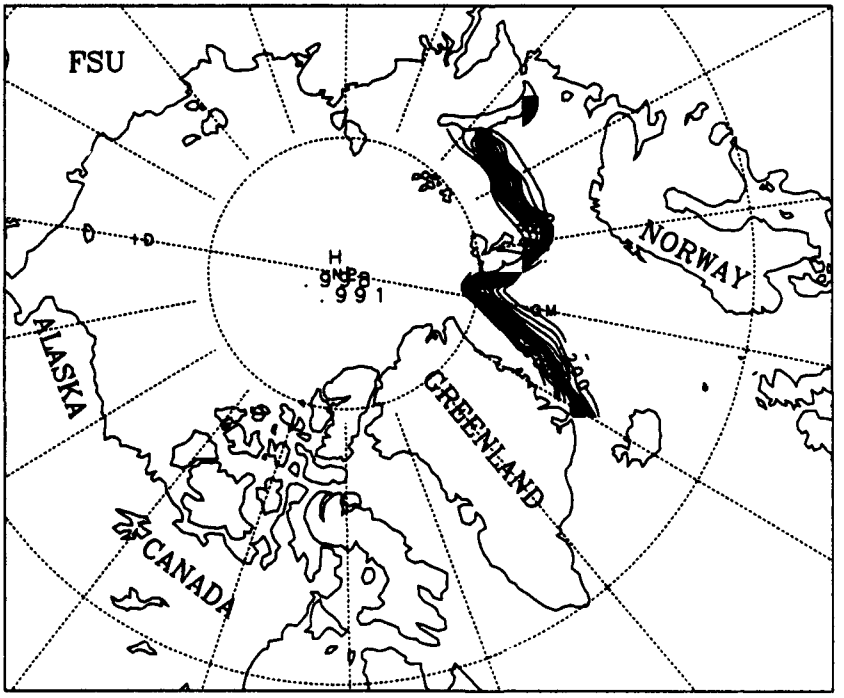

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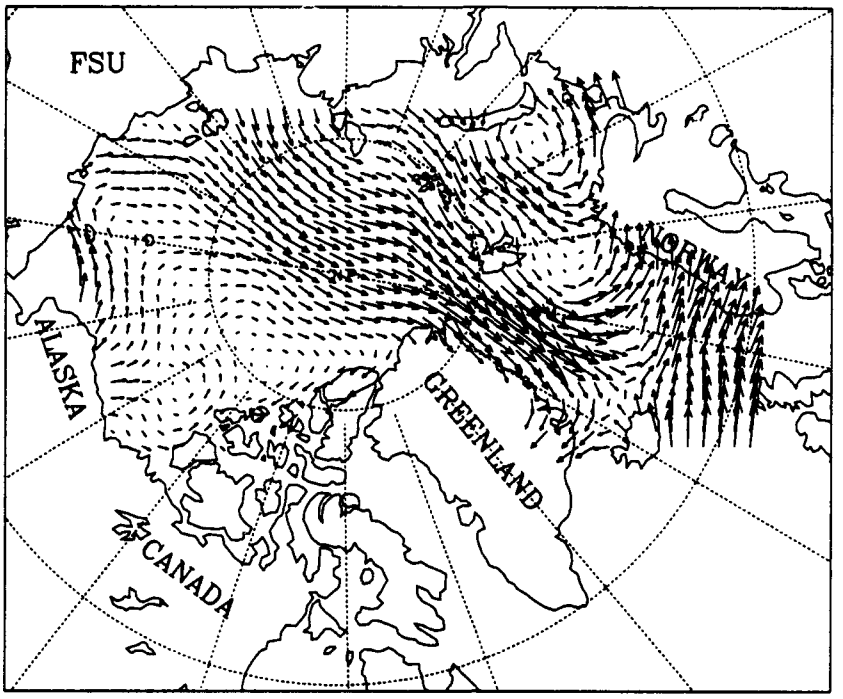

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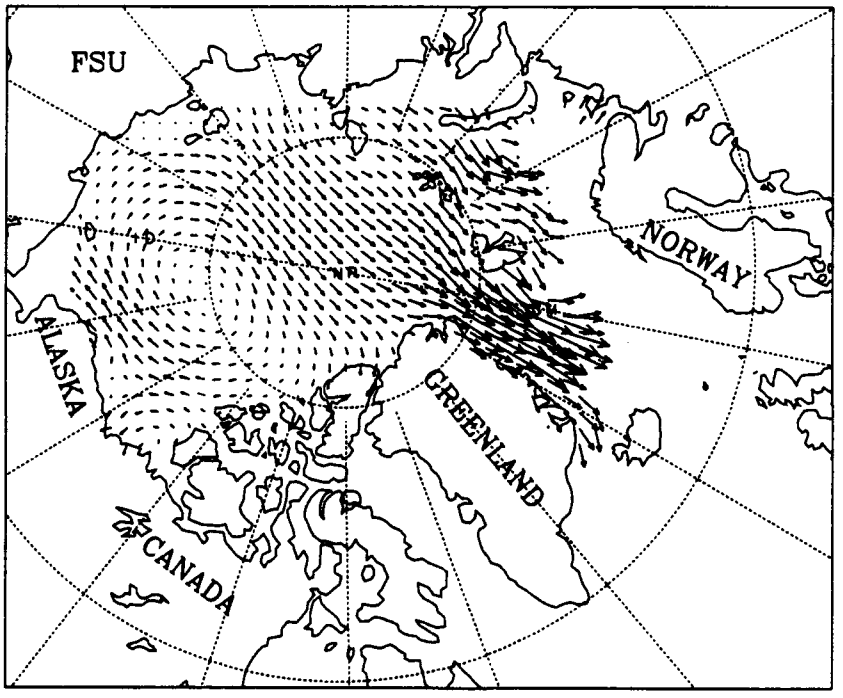

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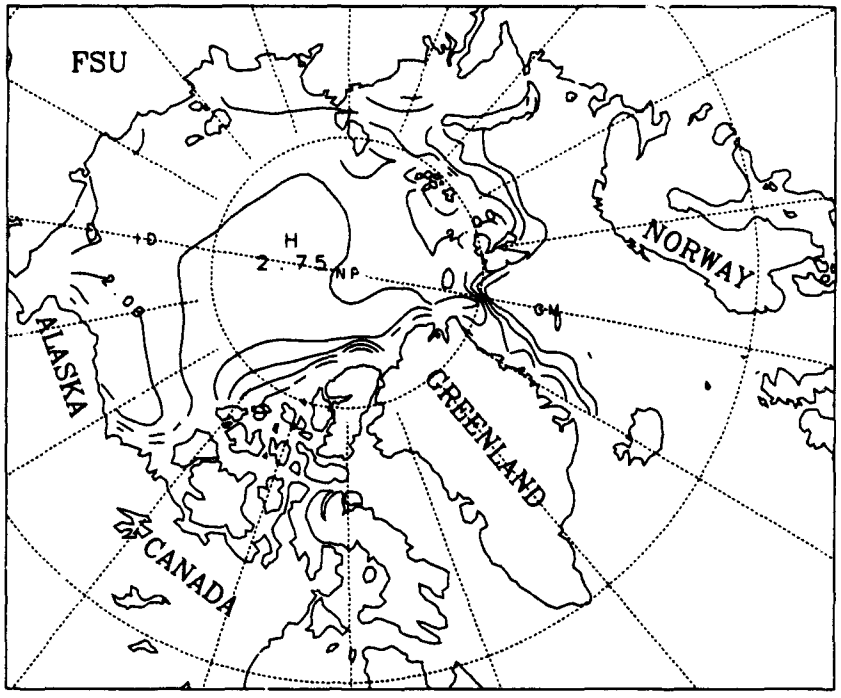

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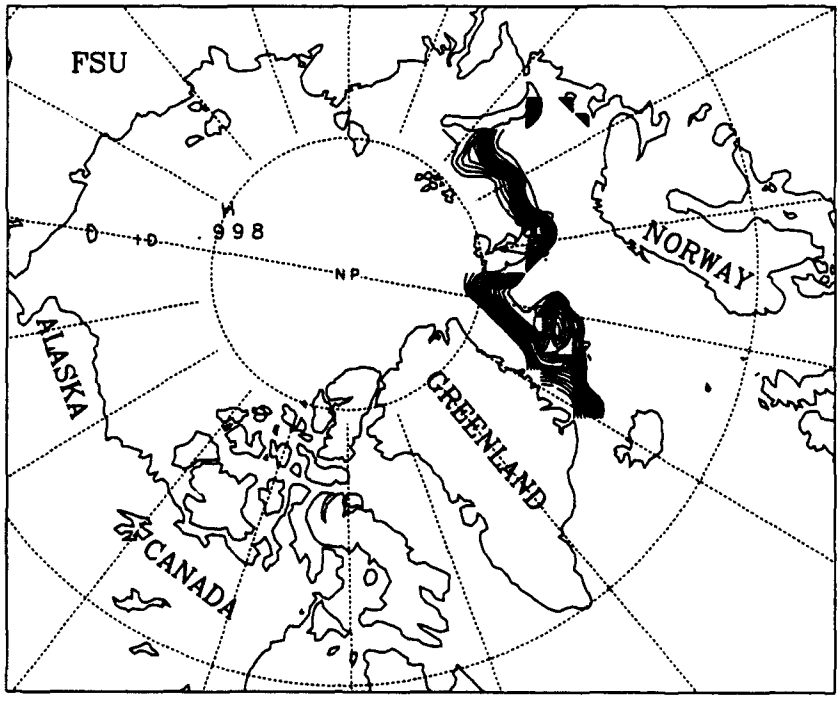

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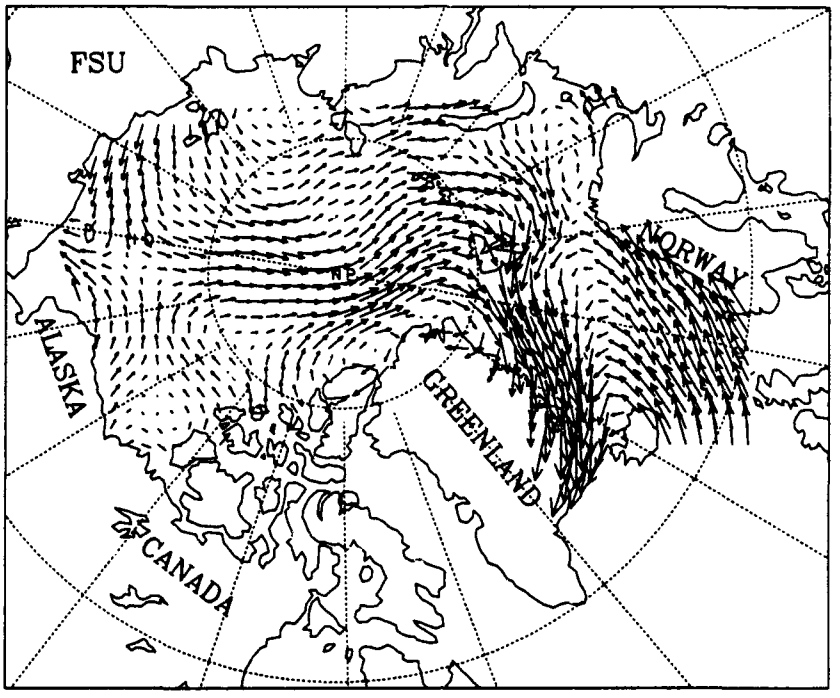

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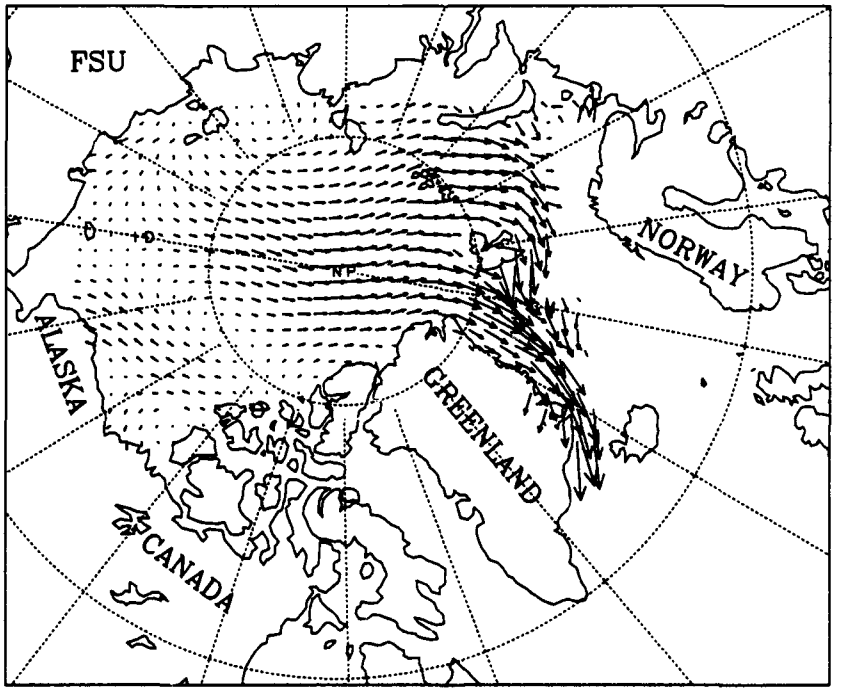

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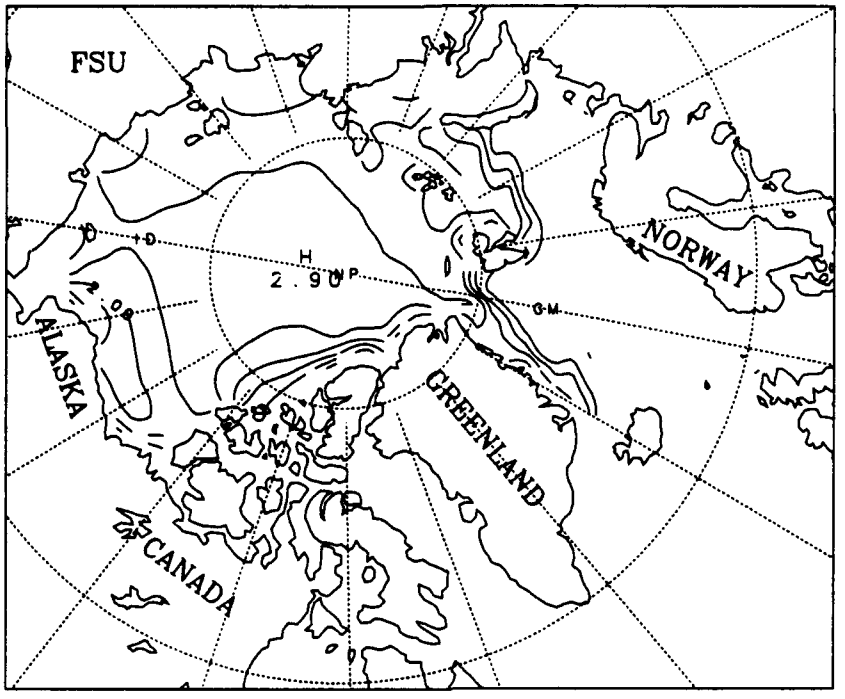

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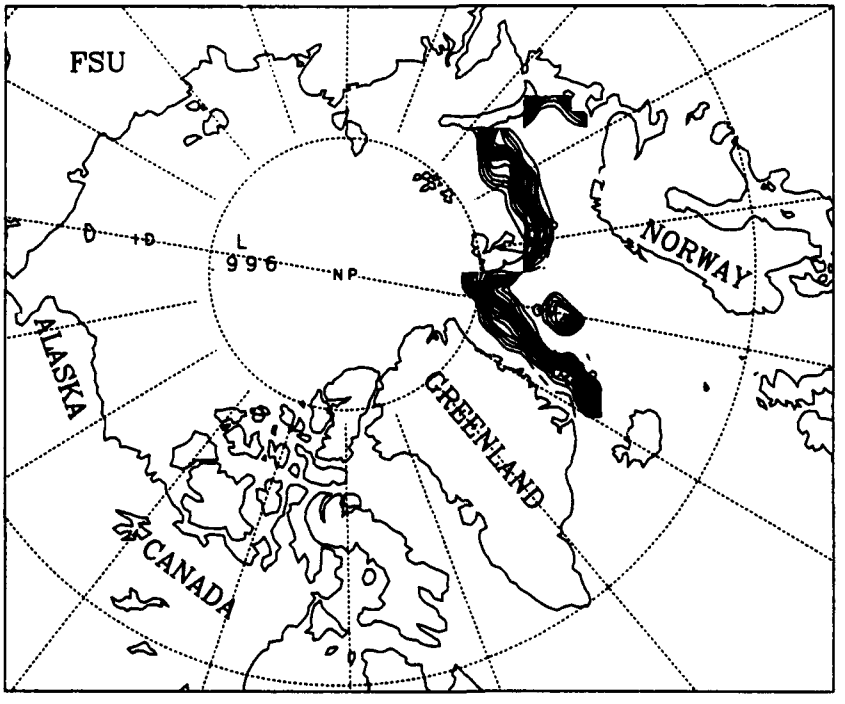

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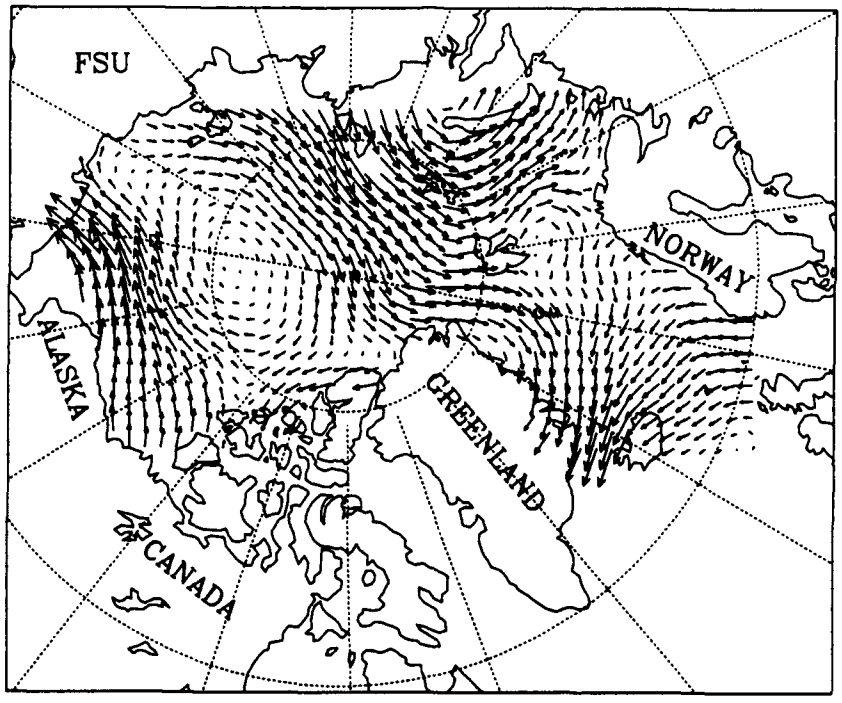

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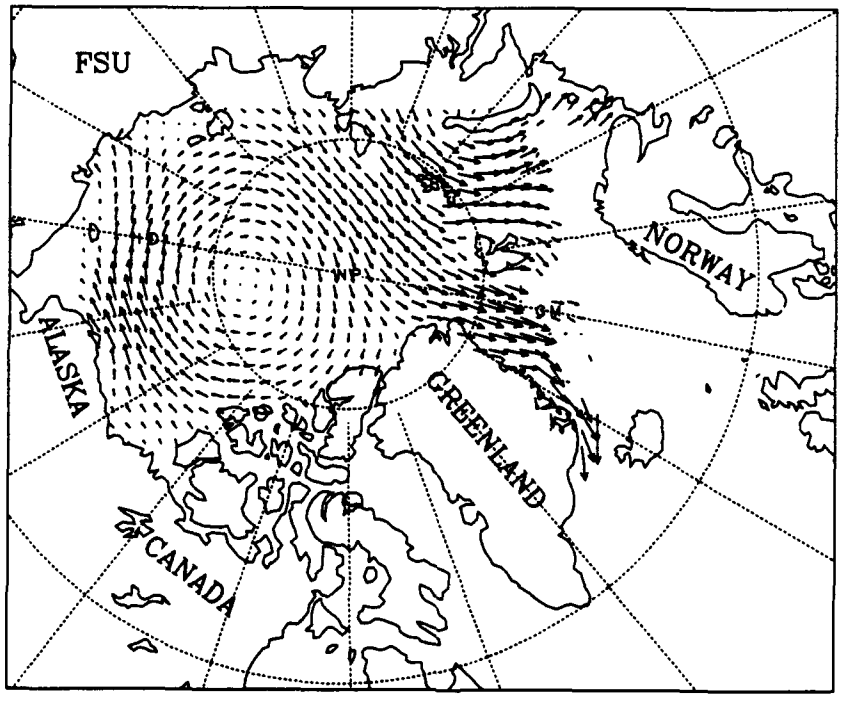

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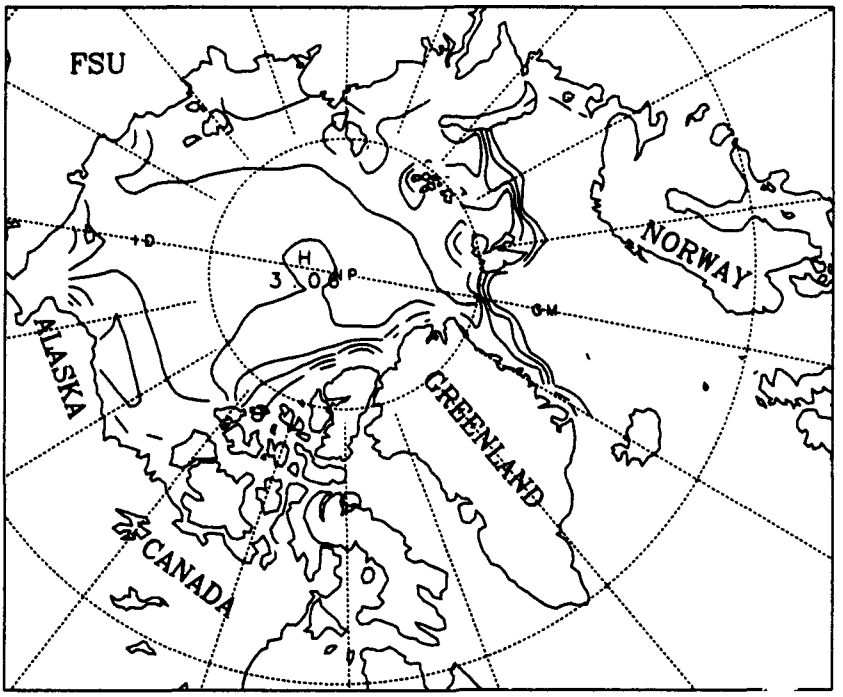

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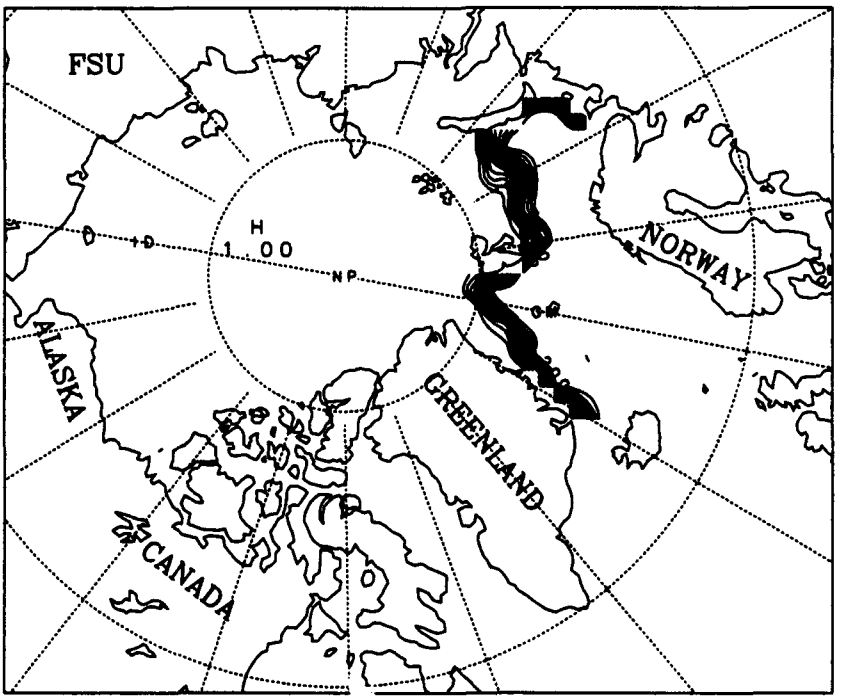

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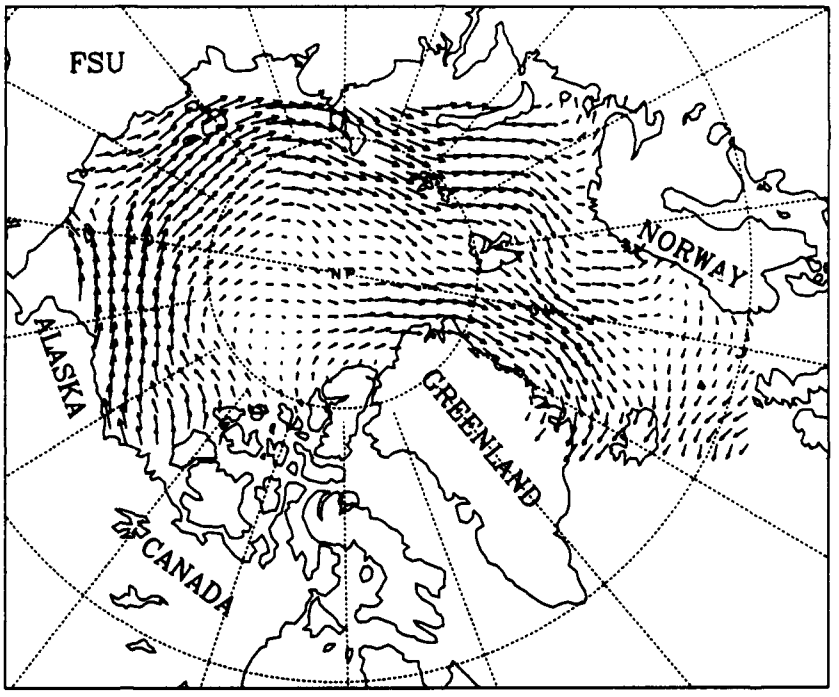

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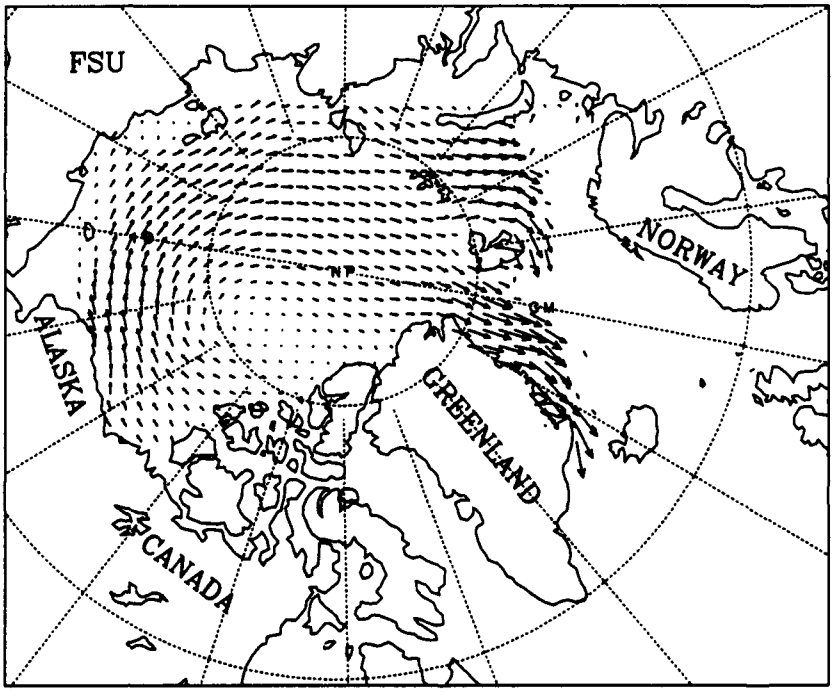

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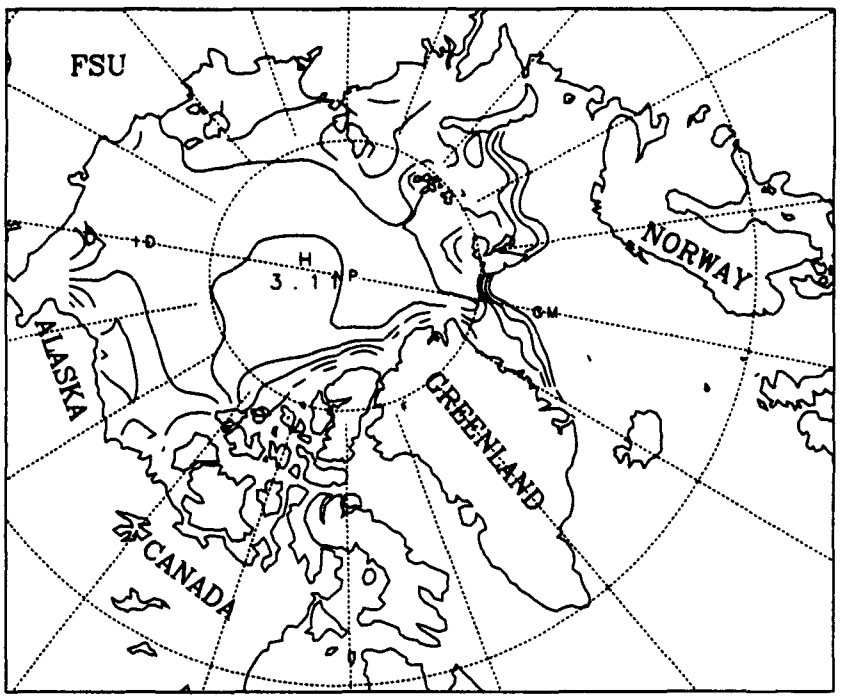

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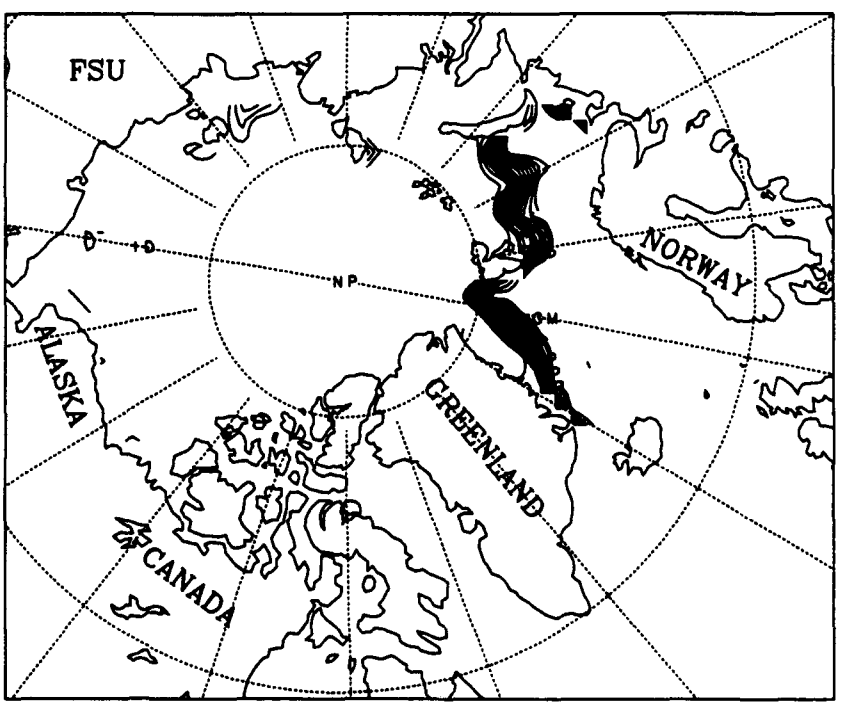

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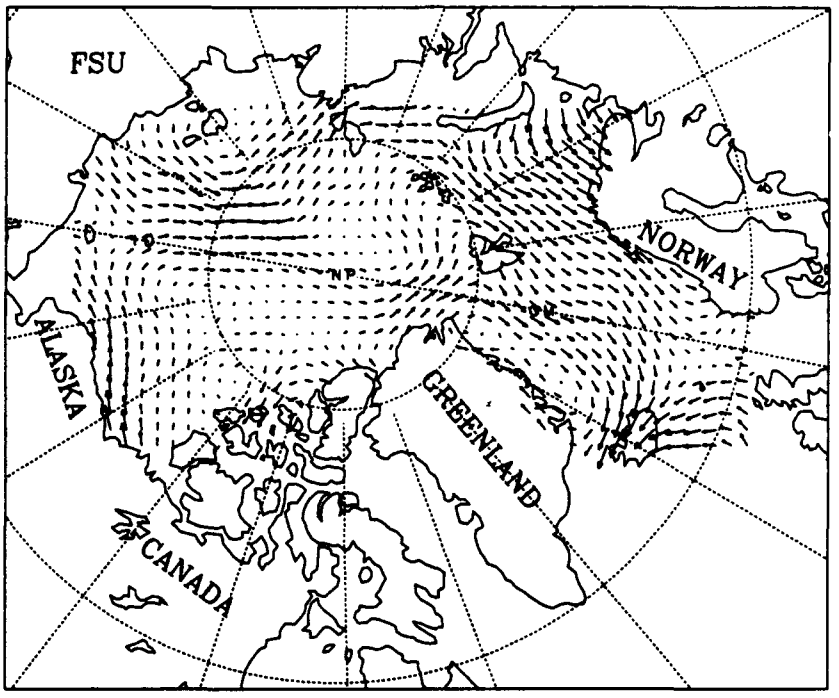

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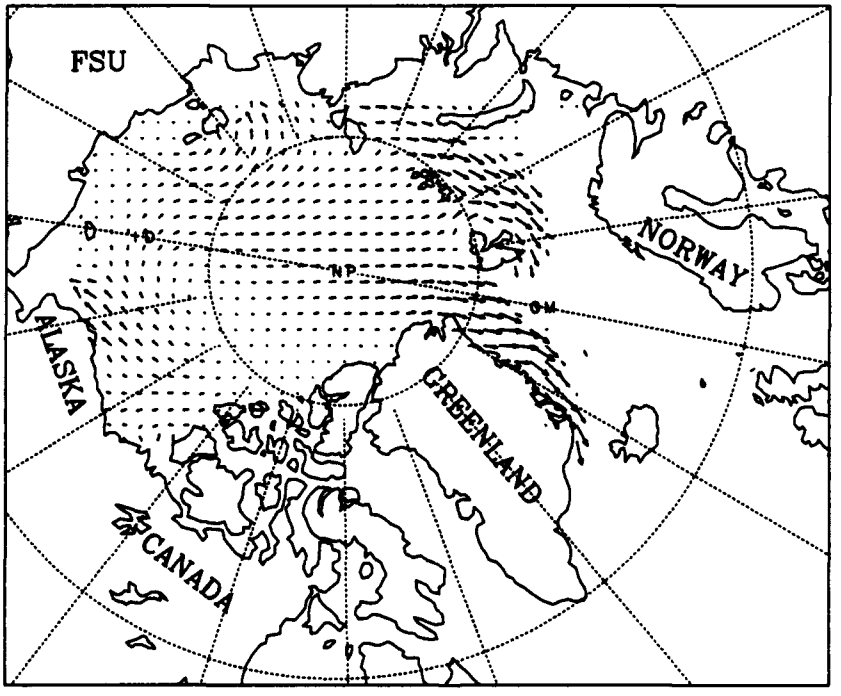

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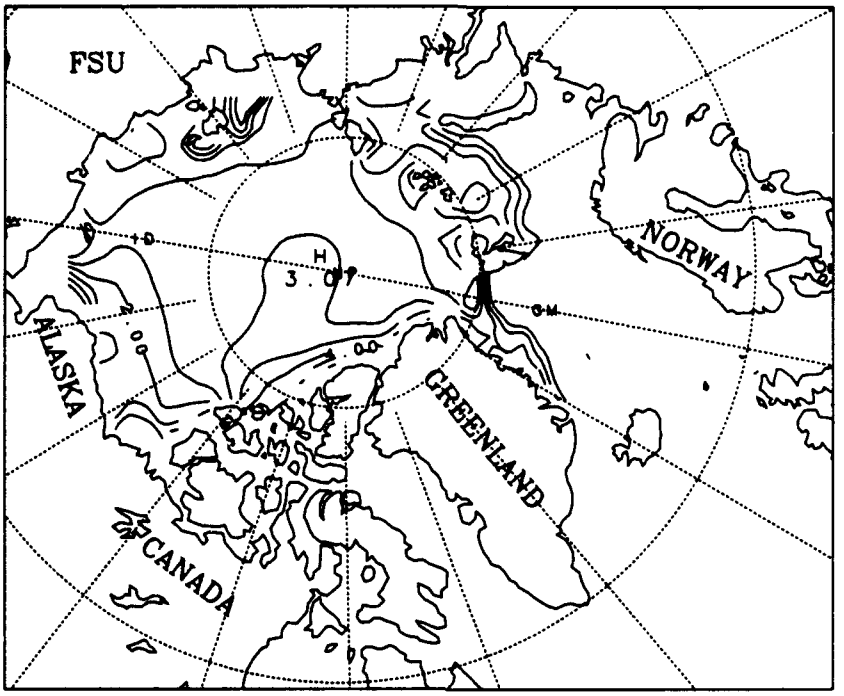

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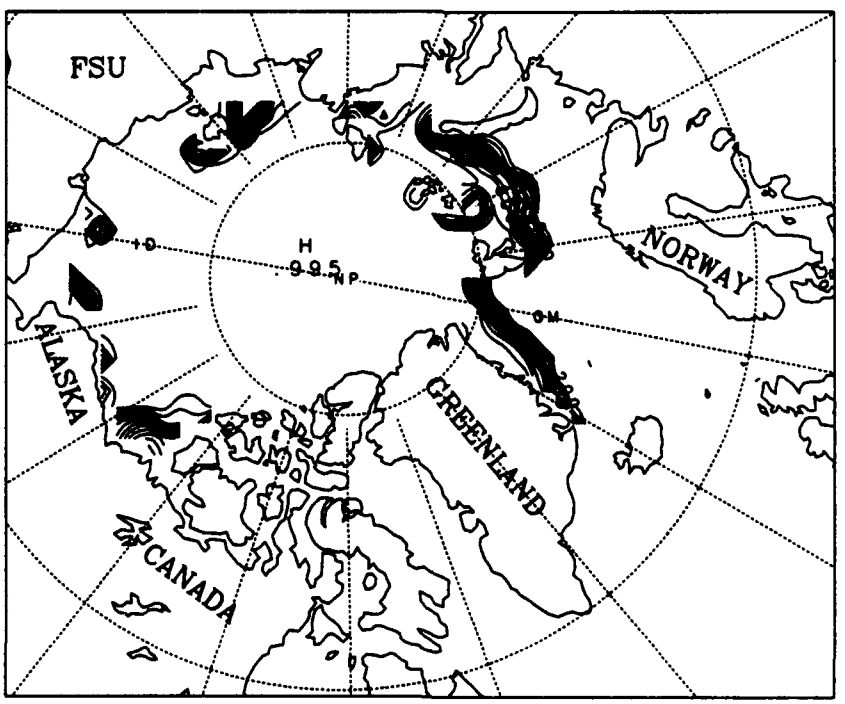

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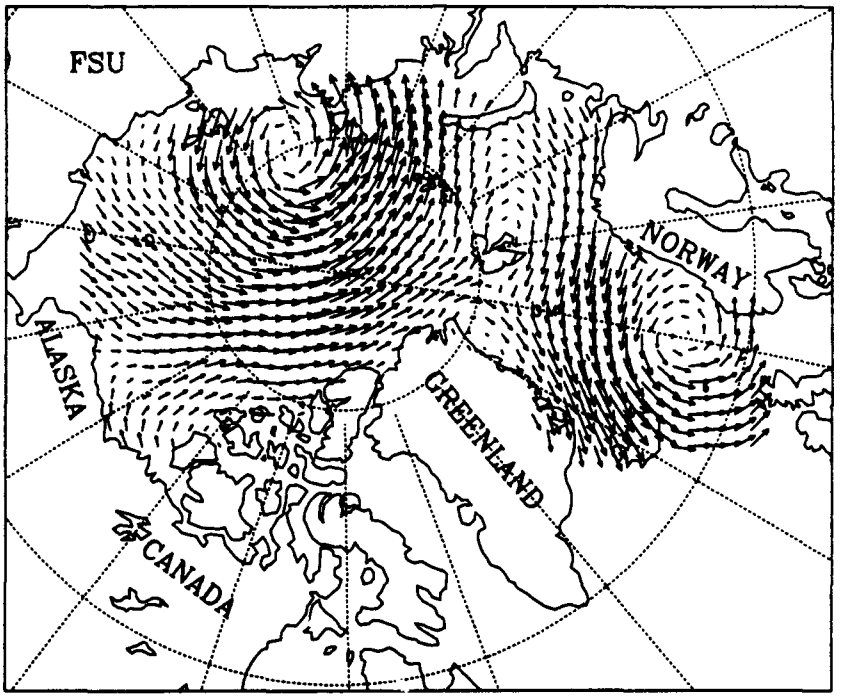

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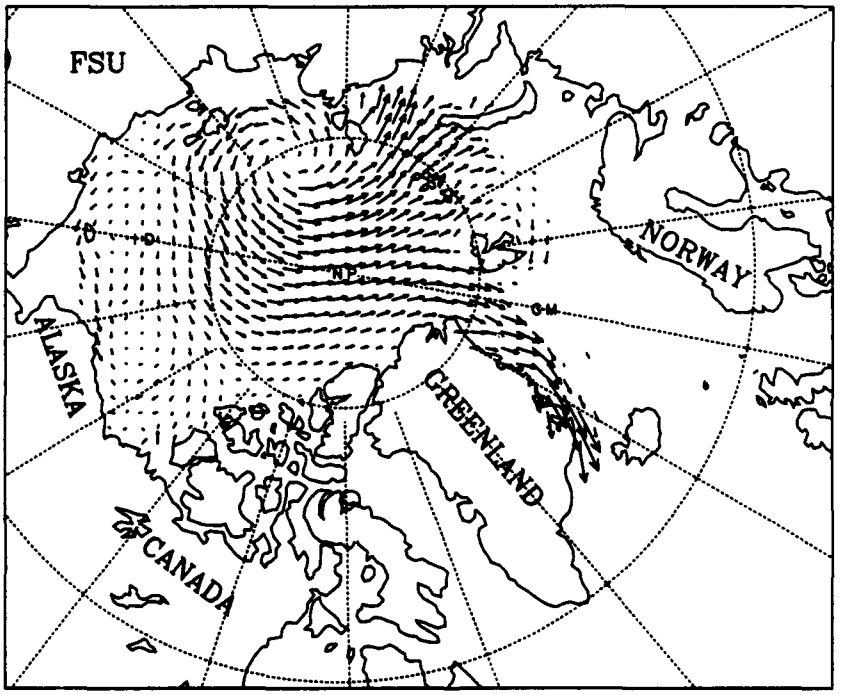

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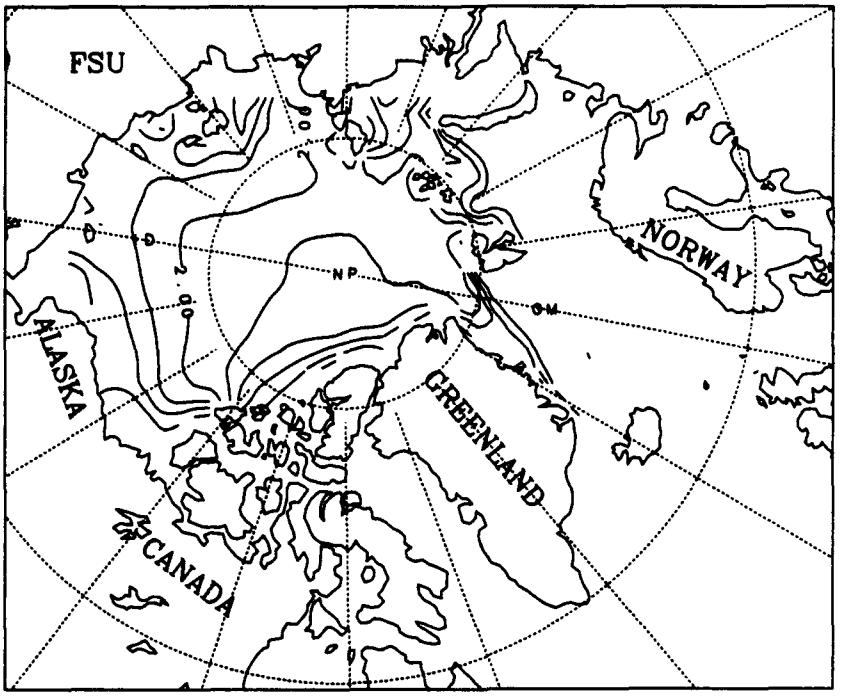
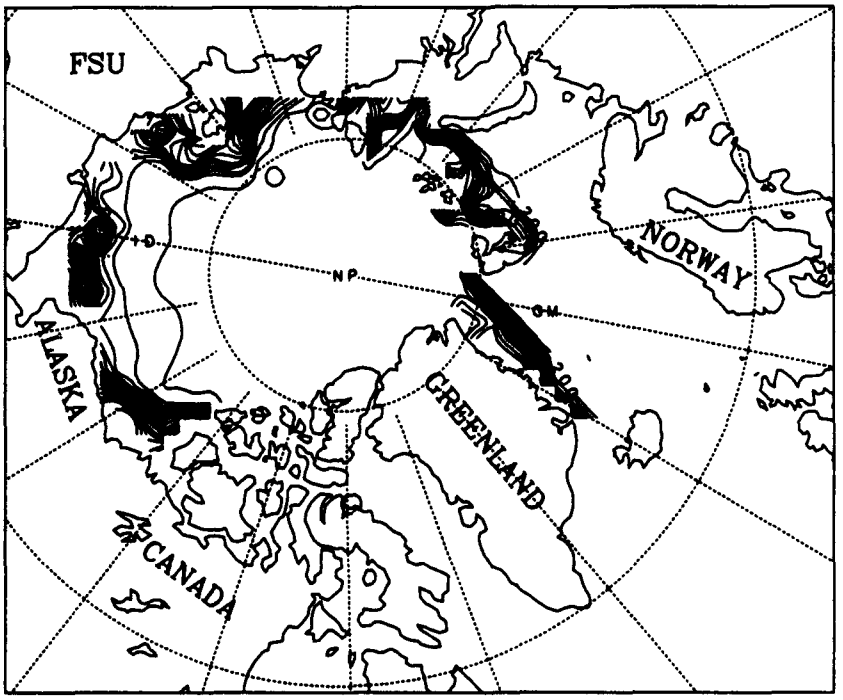
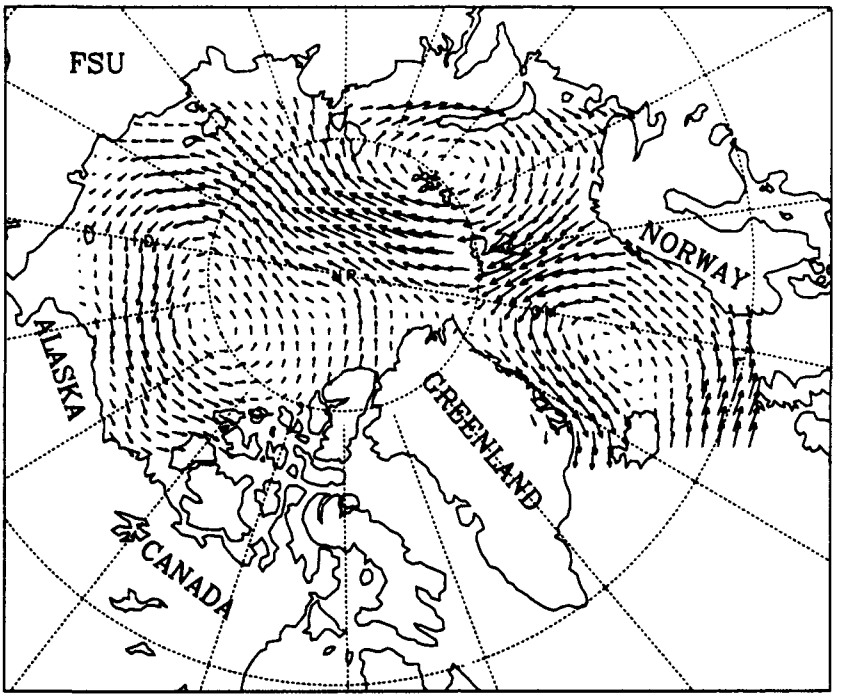
ICE THICKNESS 1993 JULY



ICE CONCENTRATION 1993 JULY



WIND VELOCITIES 1993 AUGUST



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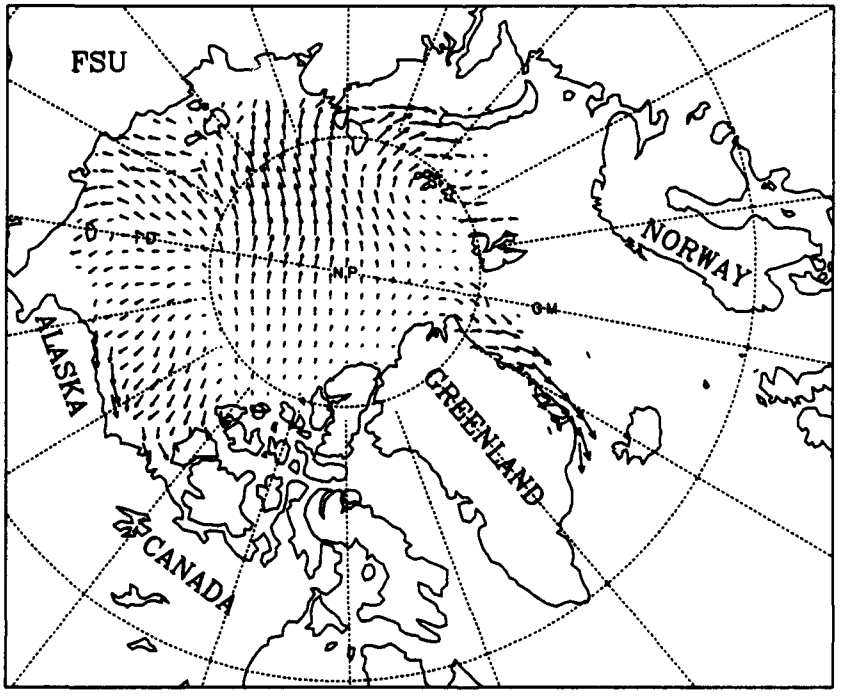
MAXIMUM VECTOR

ICE VELOCITIES 1993 AUGUST



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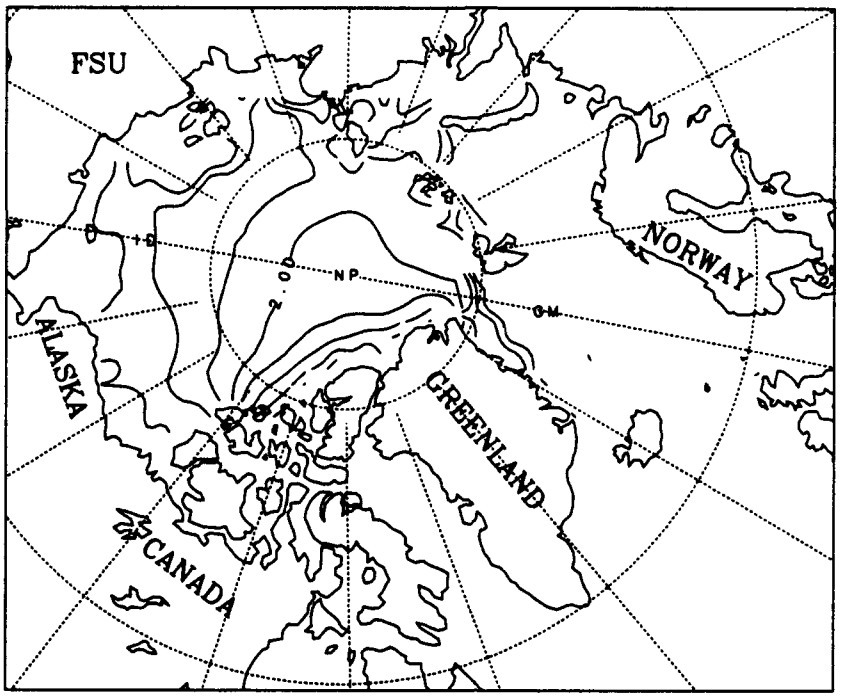
MAXIMUM VECTOR

ICE THICKNESS 1993 AUGUST



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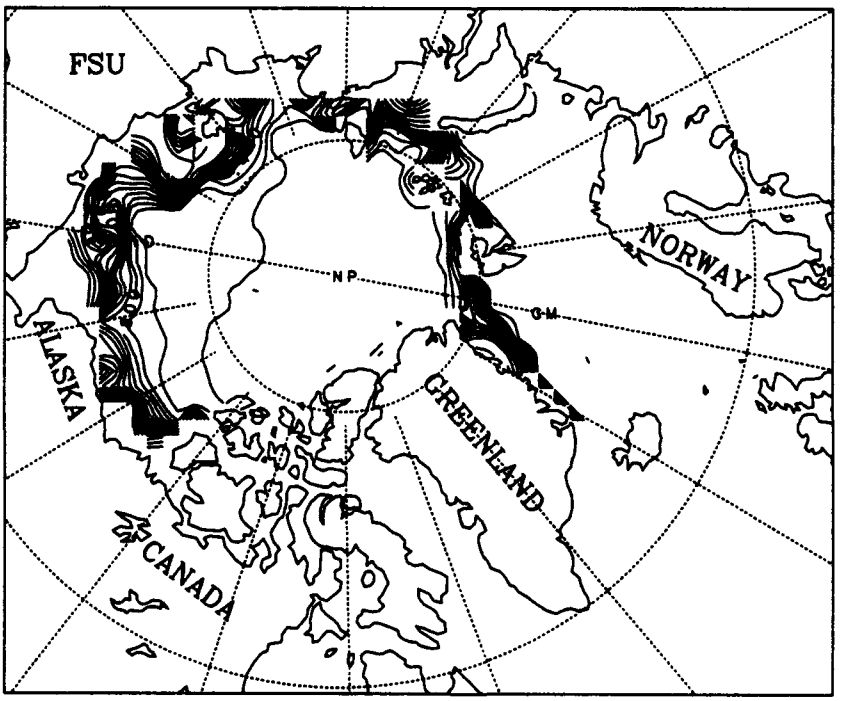
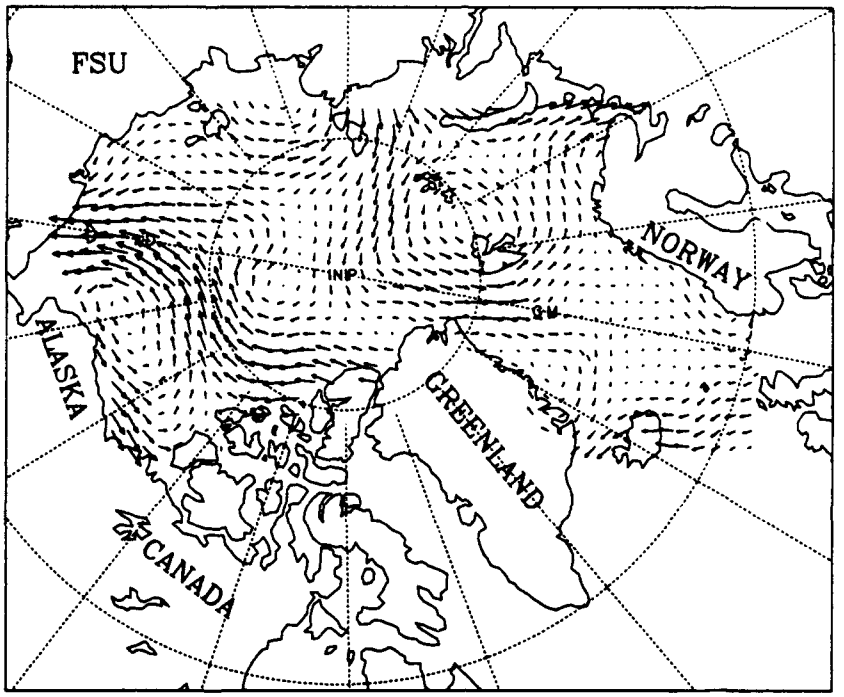


WIND VELOCITIES 1993 SEPTEMBER



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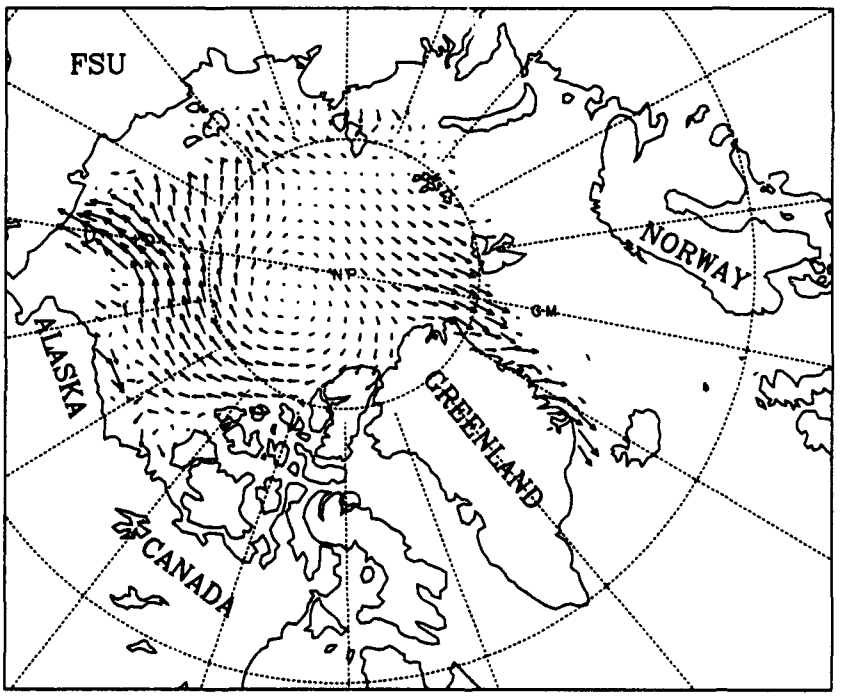

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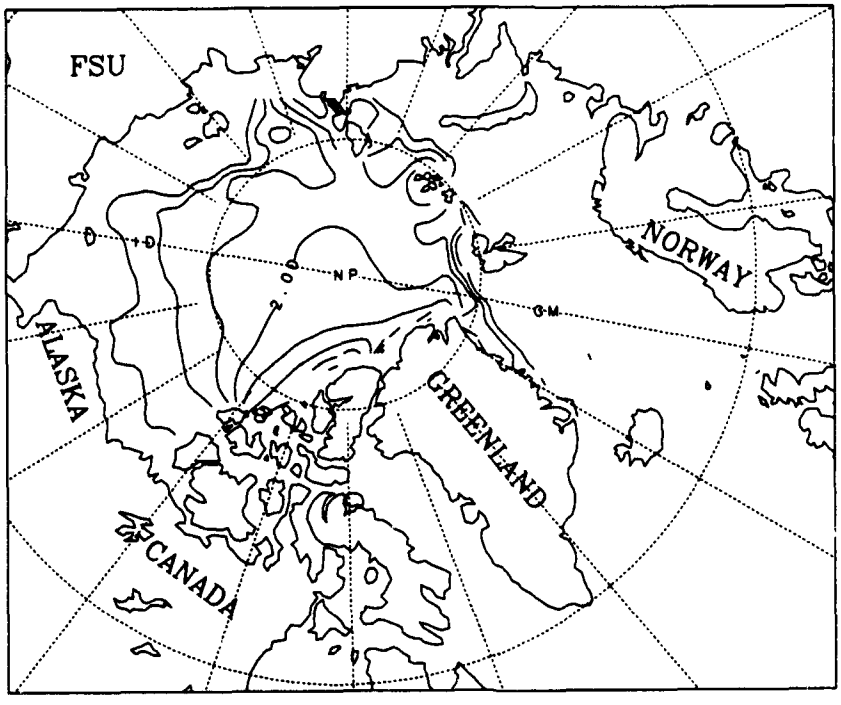

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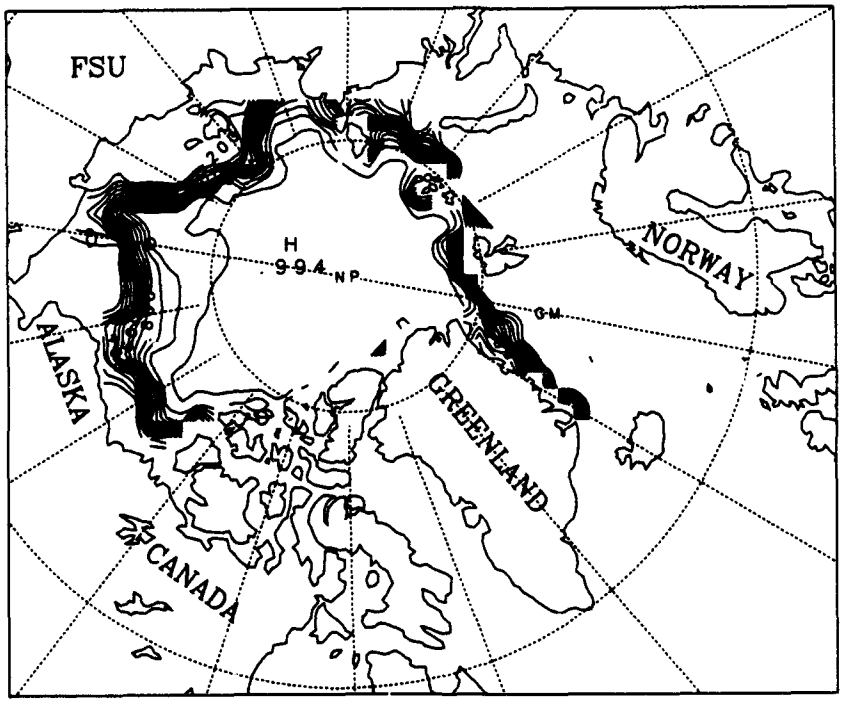
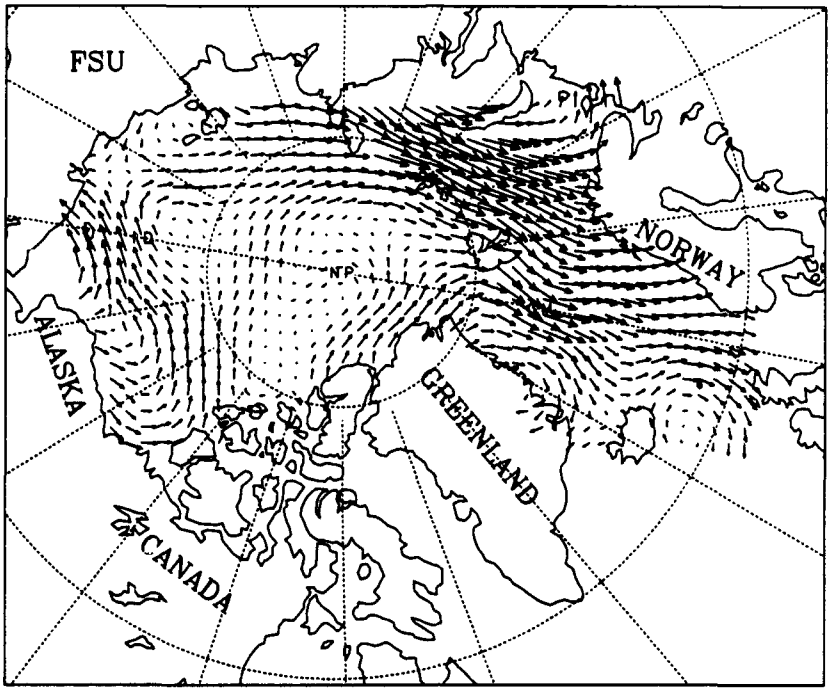


WIND VELOCITIES 1993 OCTOBER



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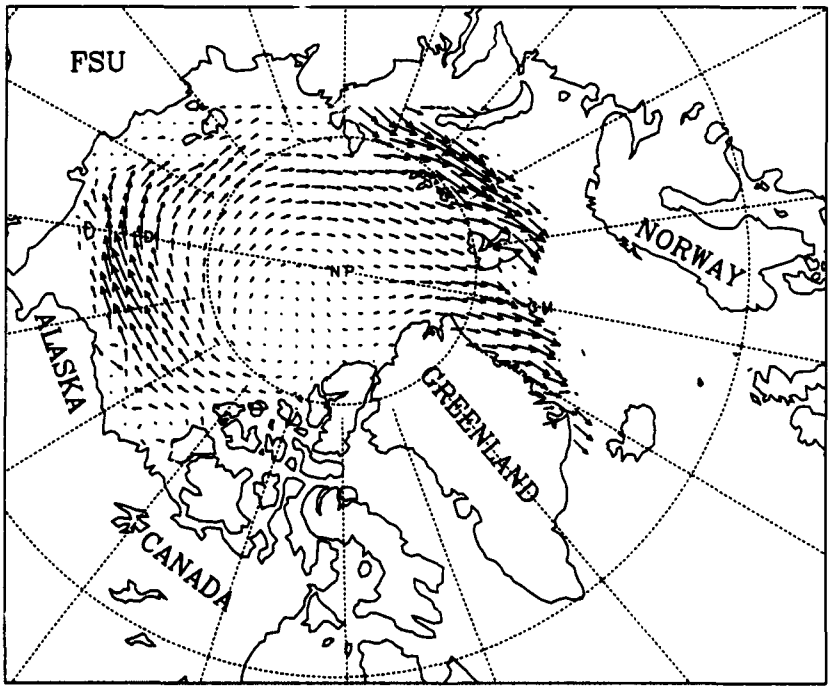

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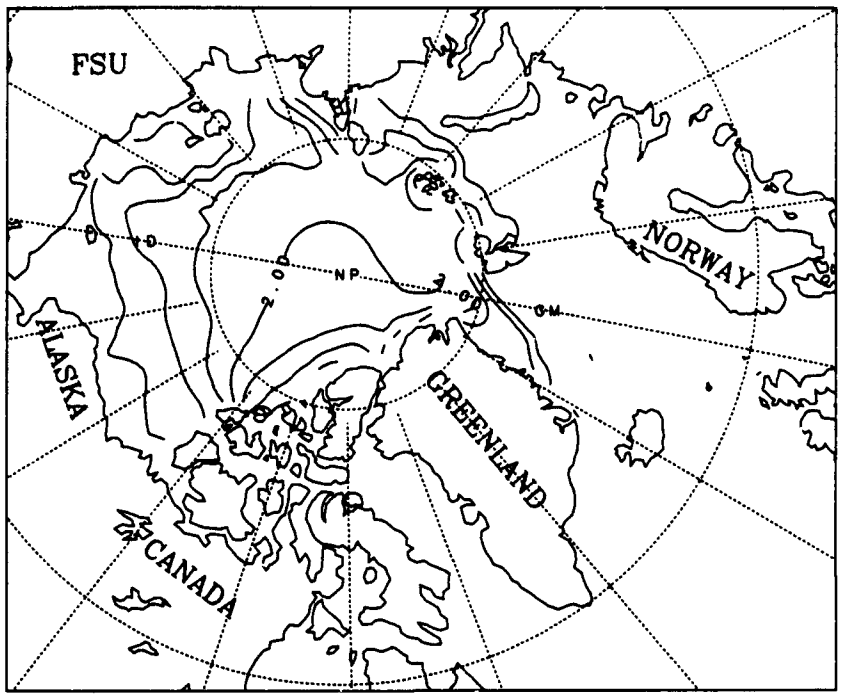

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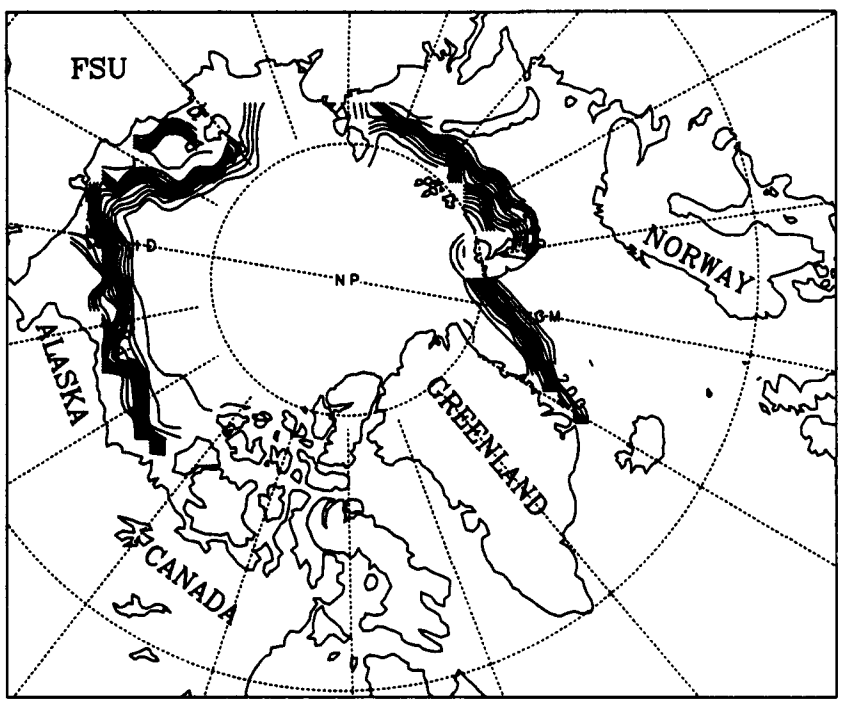
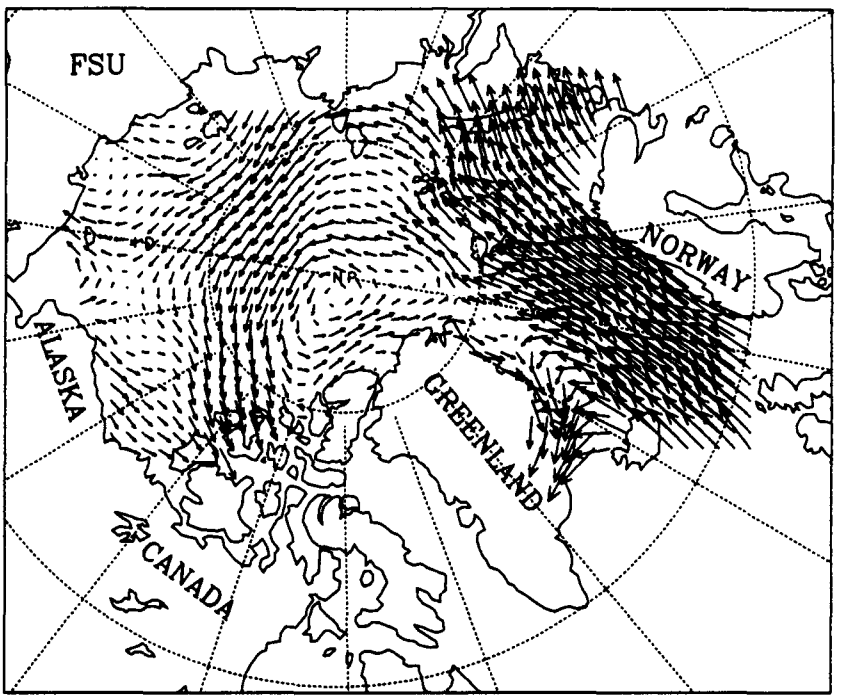


WIND VELOCITIES 1993 NOVEMBER



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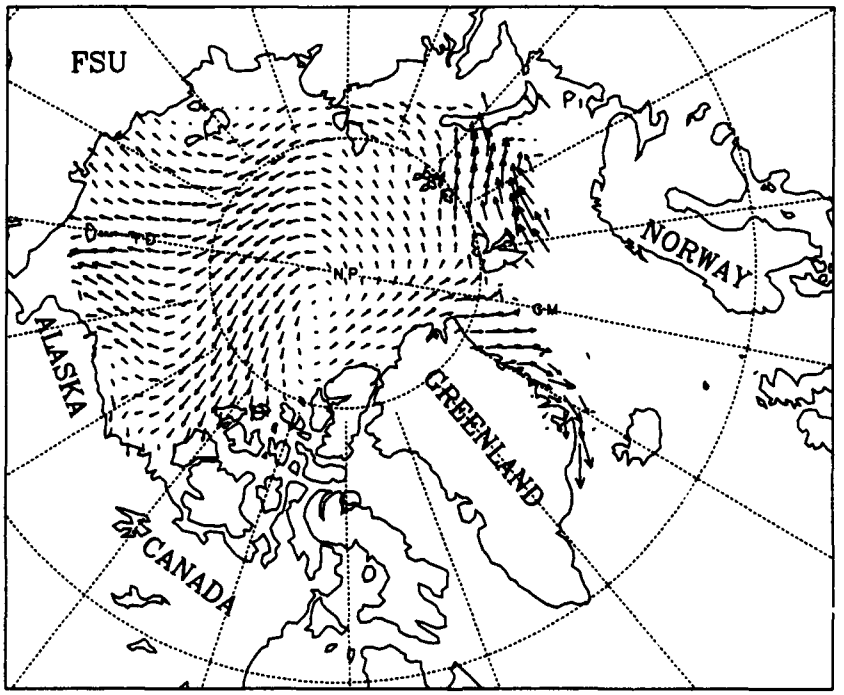

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MAXIMUM VECTOR

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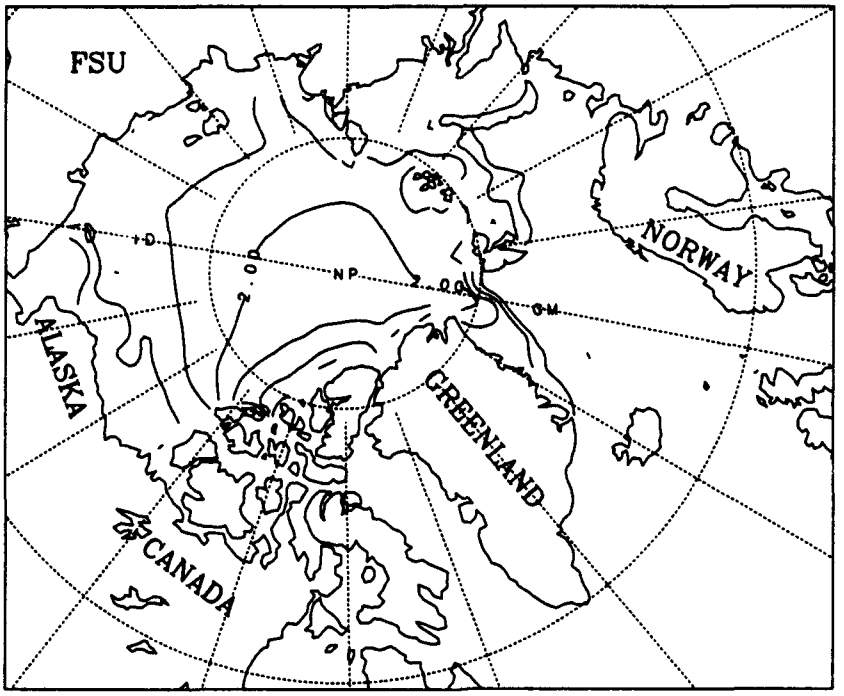

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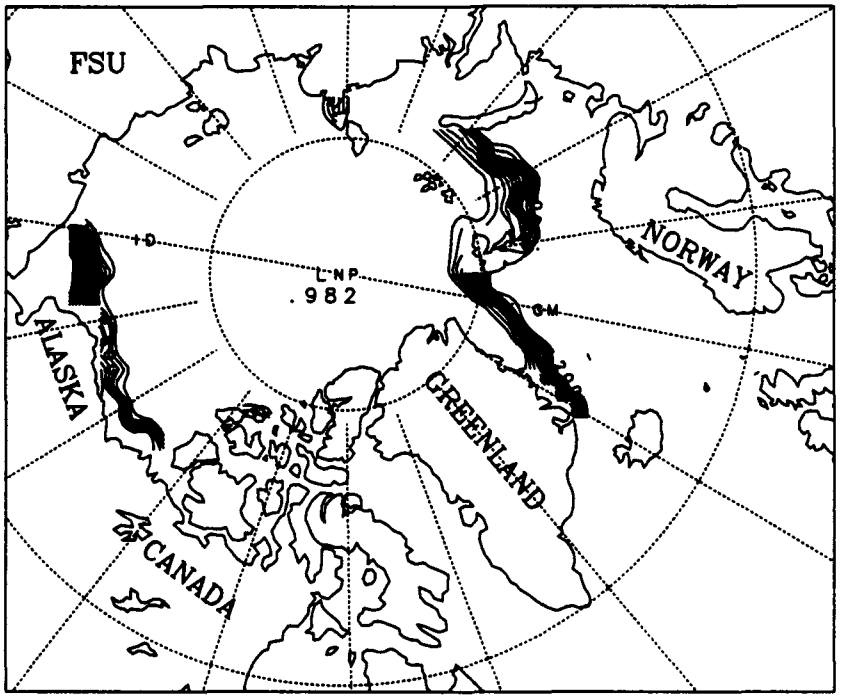

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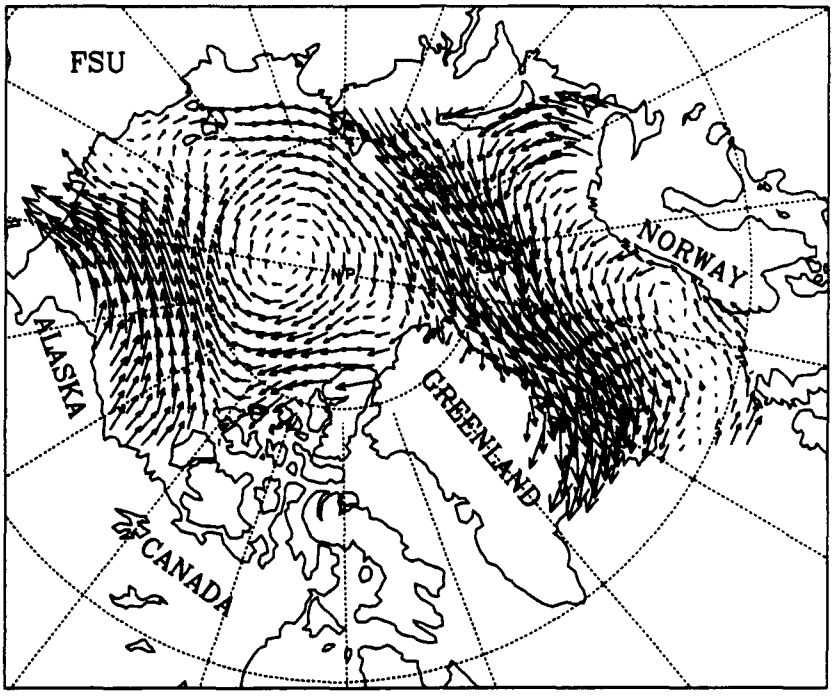

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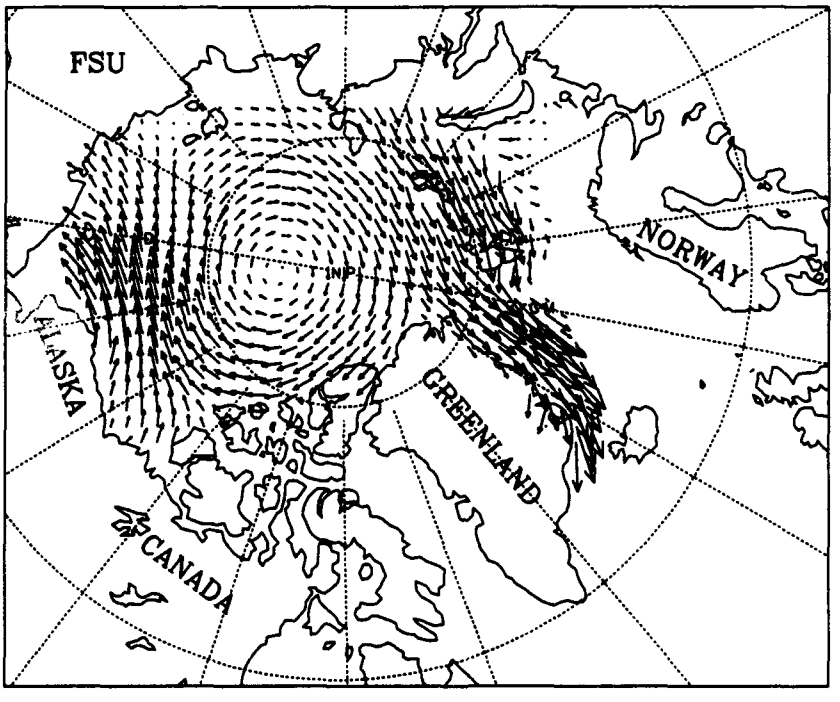

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MAXIMUM VECTOR

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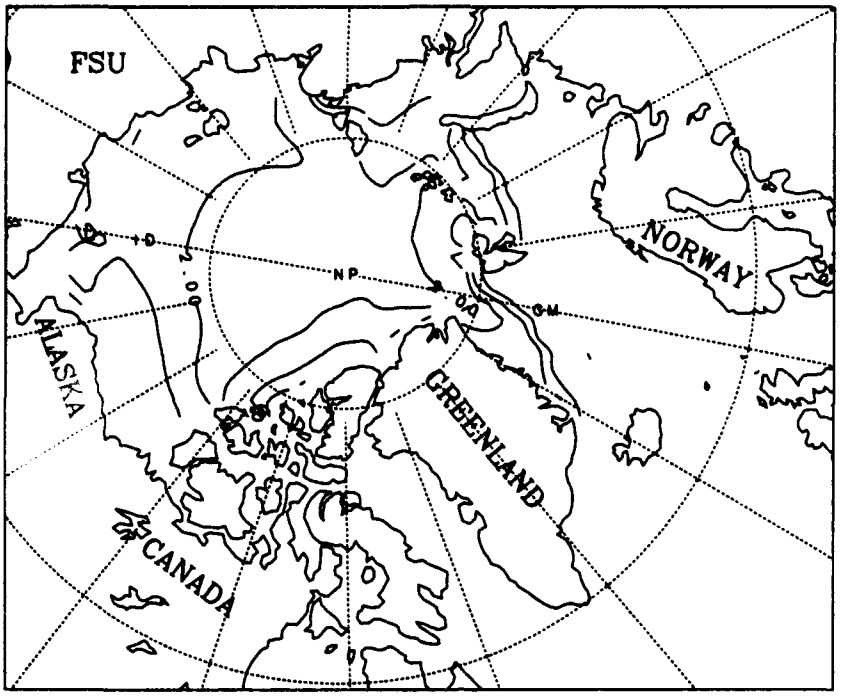

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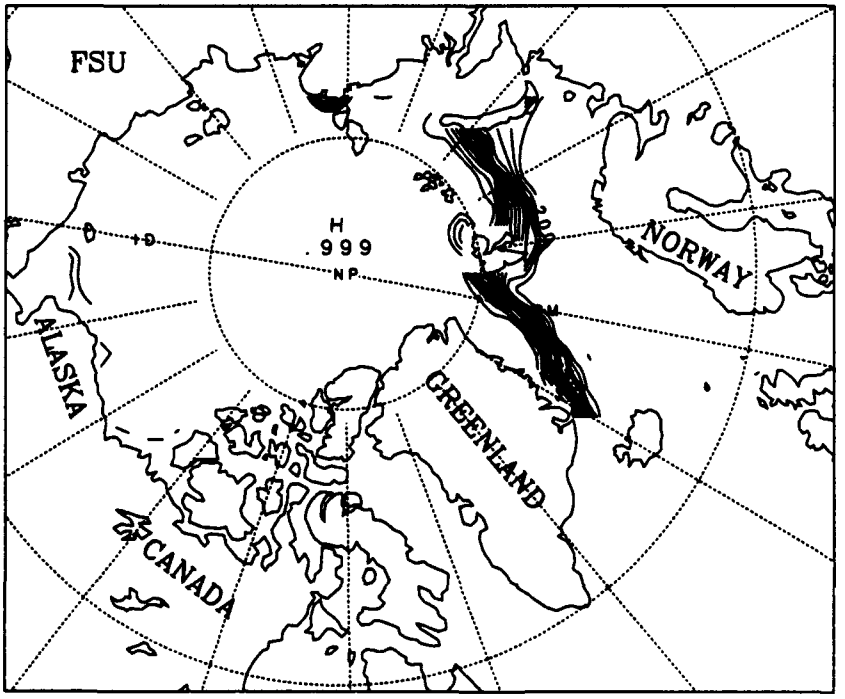


RPIPS-B MODEL GRID

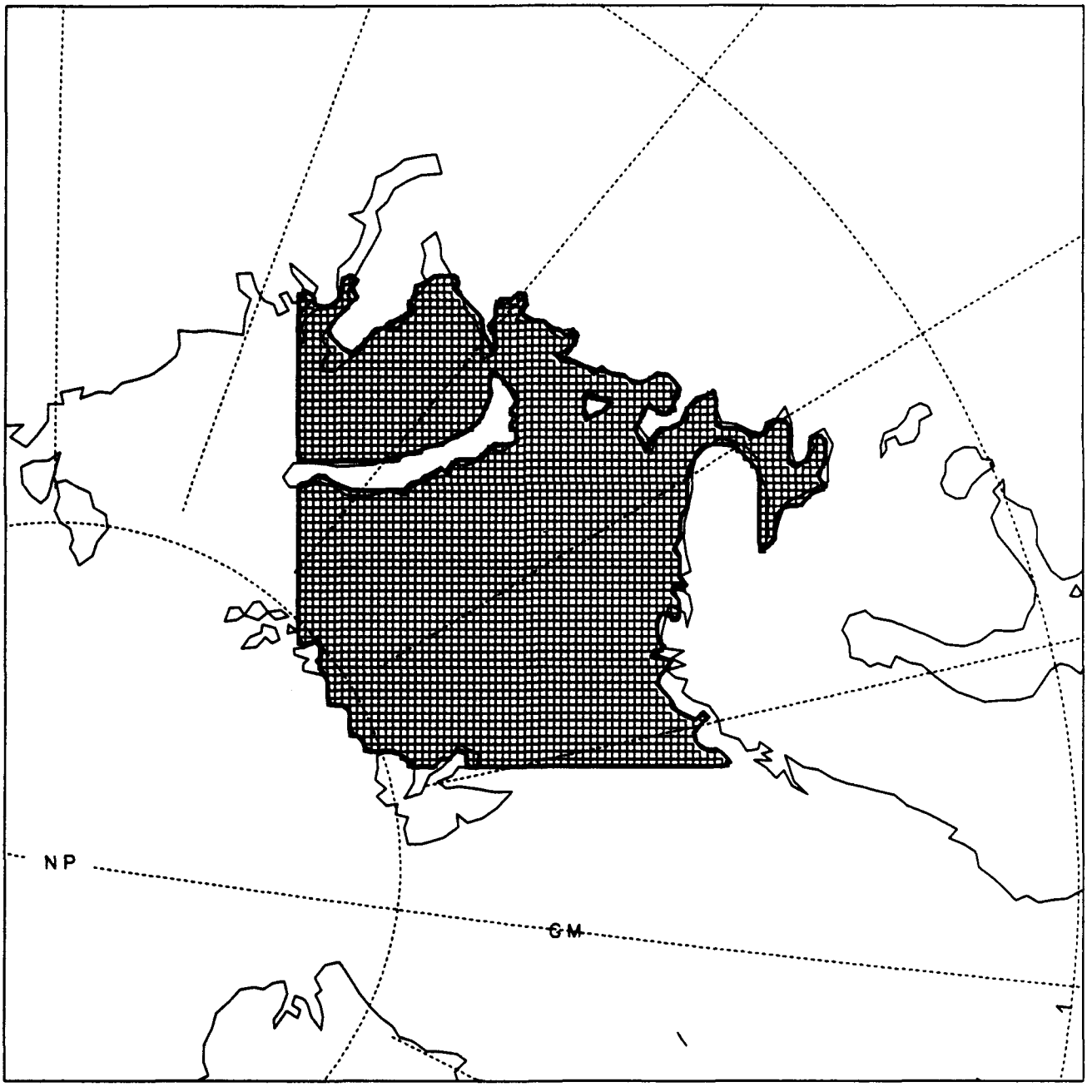
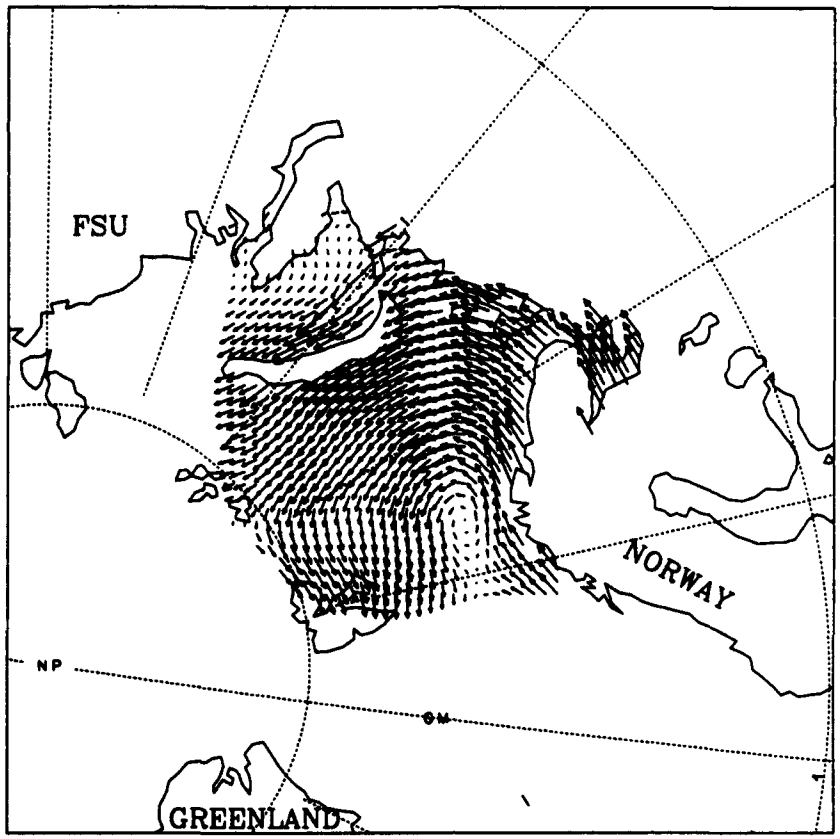


Figure 2. RPIPS-B domain with the 25-km resolution grid overlaid.

RPIPS-B 1993

MONTHLY MEANS

WIND VELOCITIES 1993 JANUARY



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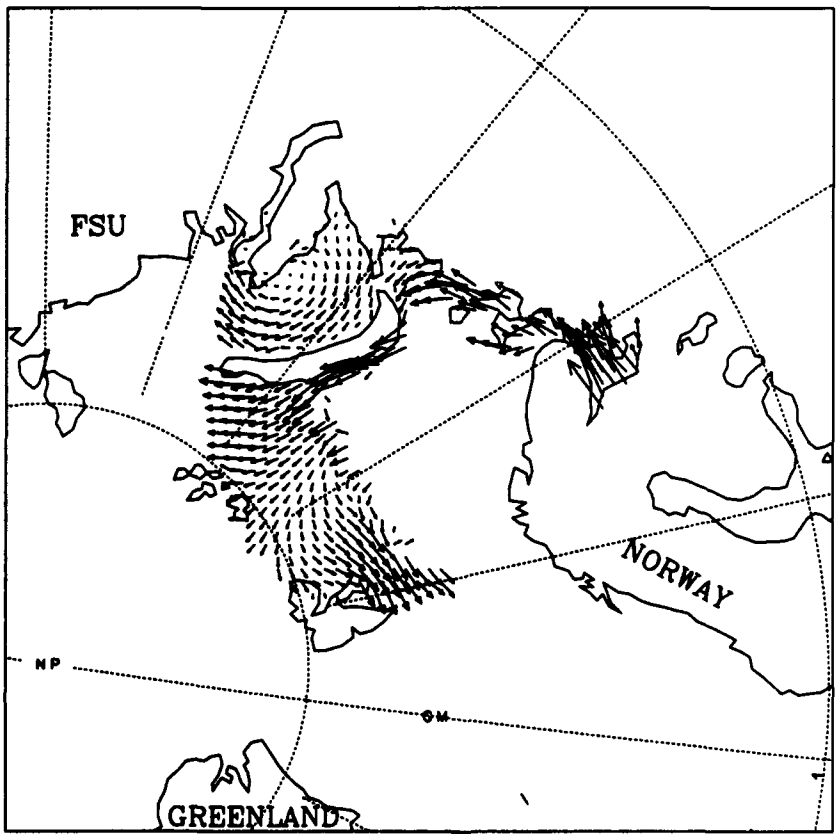
MAXIMUM VECTOR

ICE VELOCITIES 1993 JANUARY



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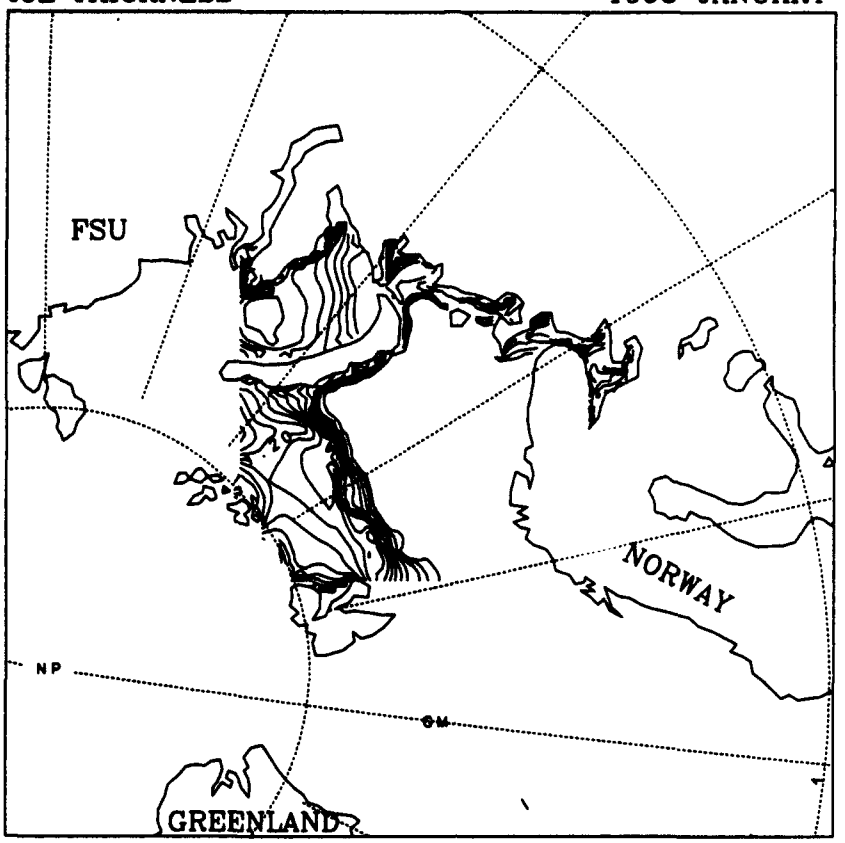
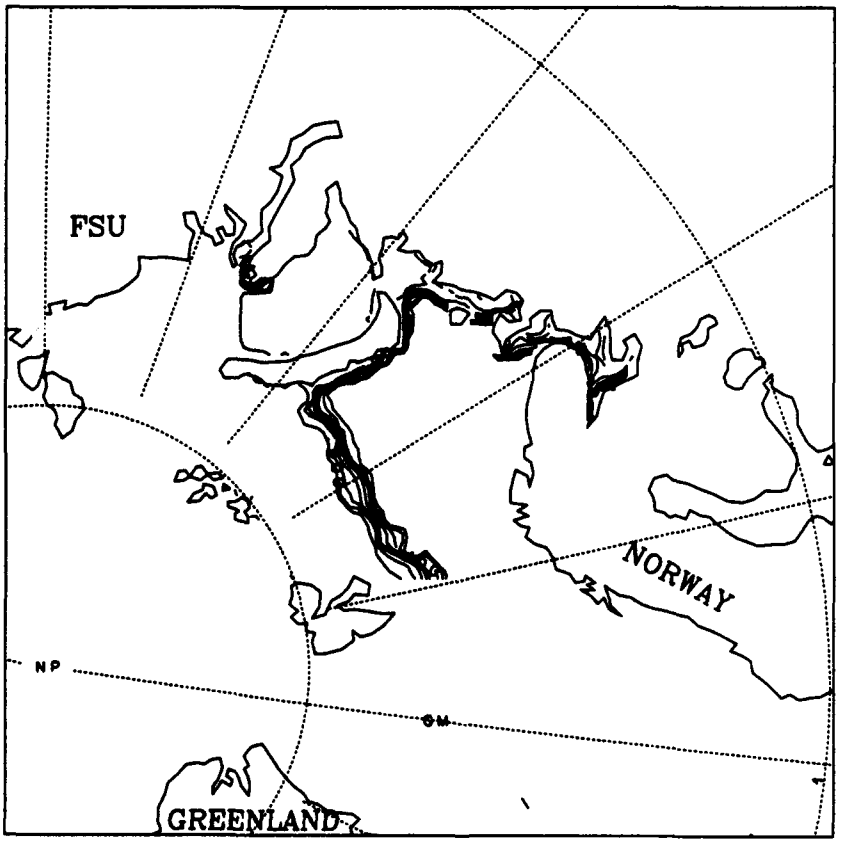
MAXIMUM VECTOR

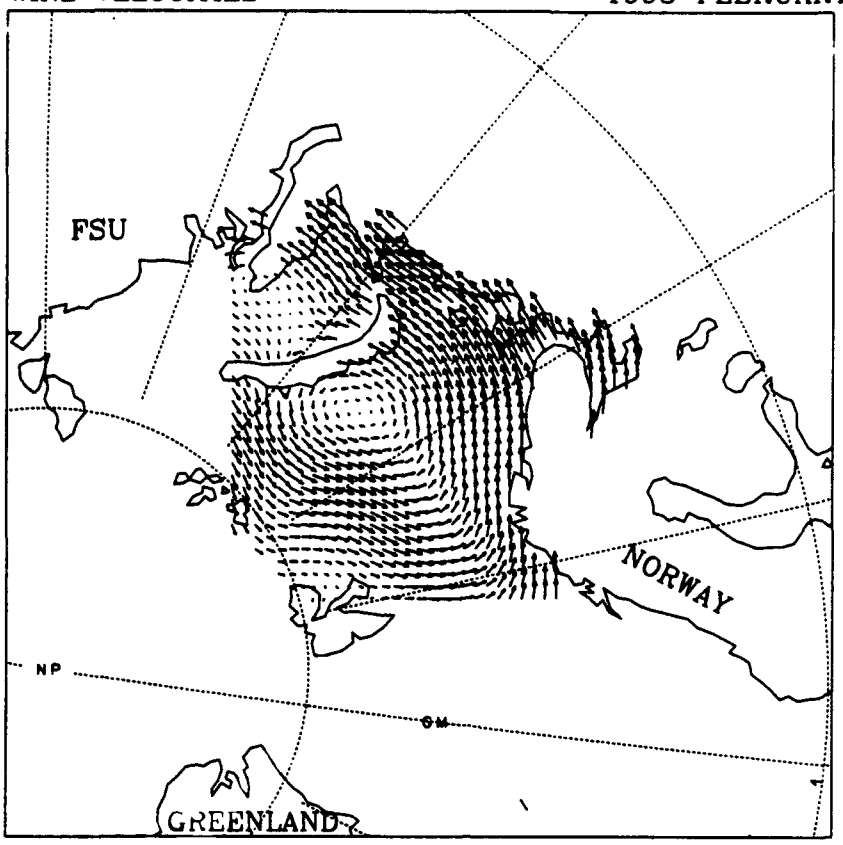
ICE THICKNESS 1993 JANUARY



ICE CONCENTRATION 1993 JANUARY



WIND VELOCITIES 1993 FEBRUARY



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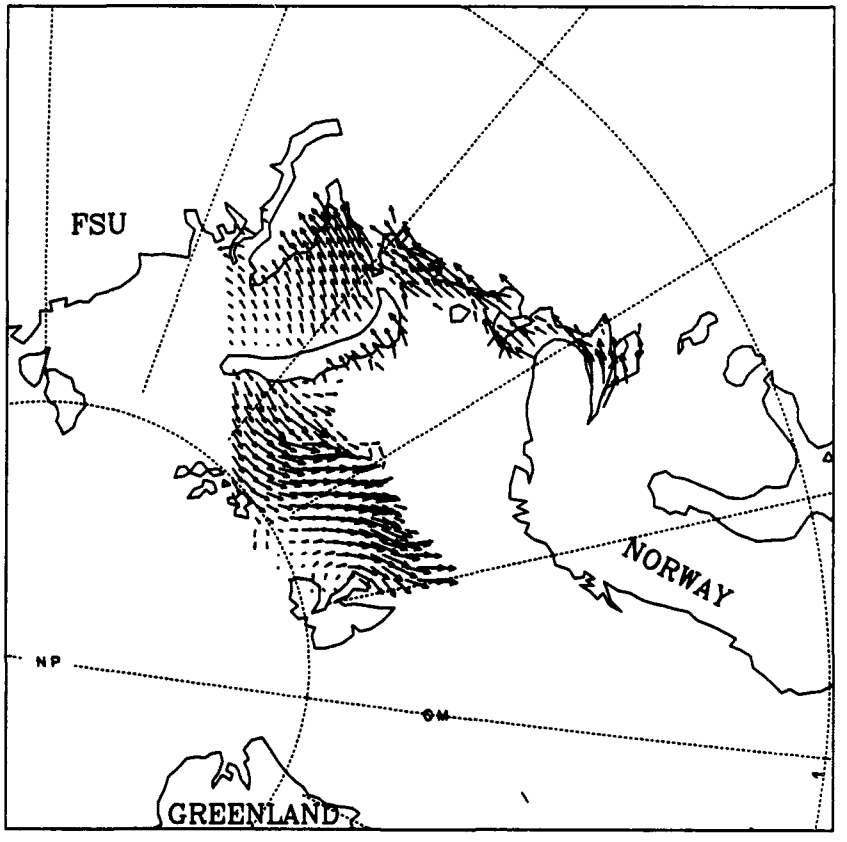
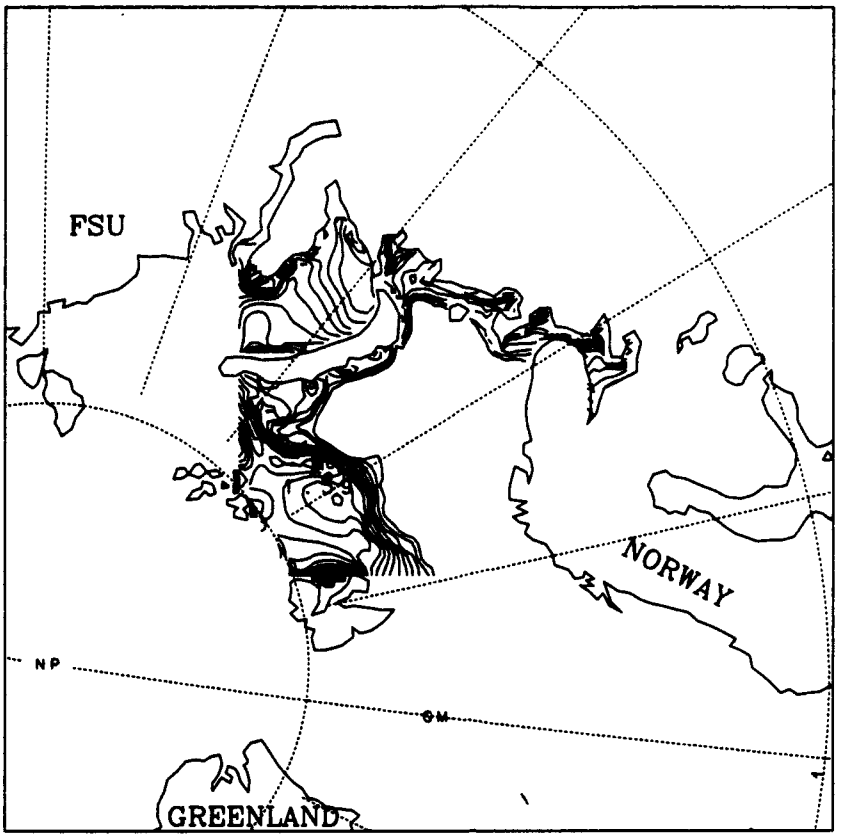


ICE THICKNESS 1993 FEBRUARY



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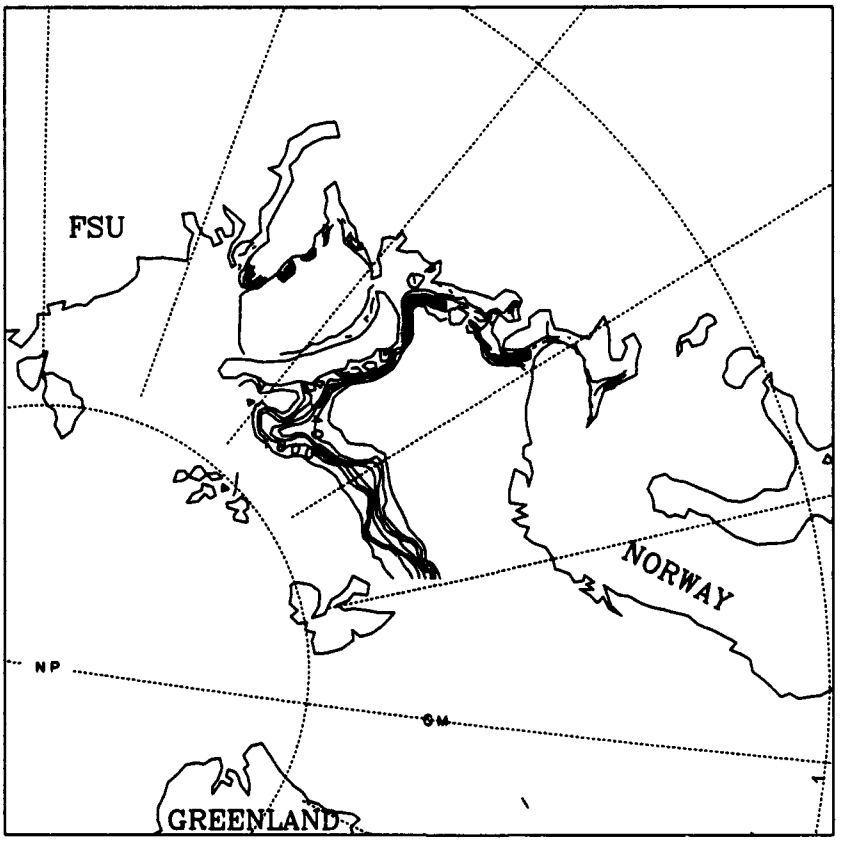
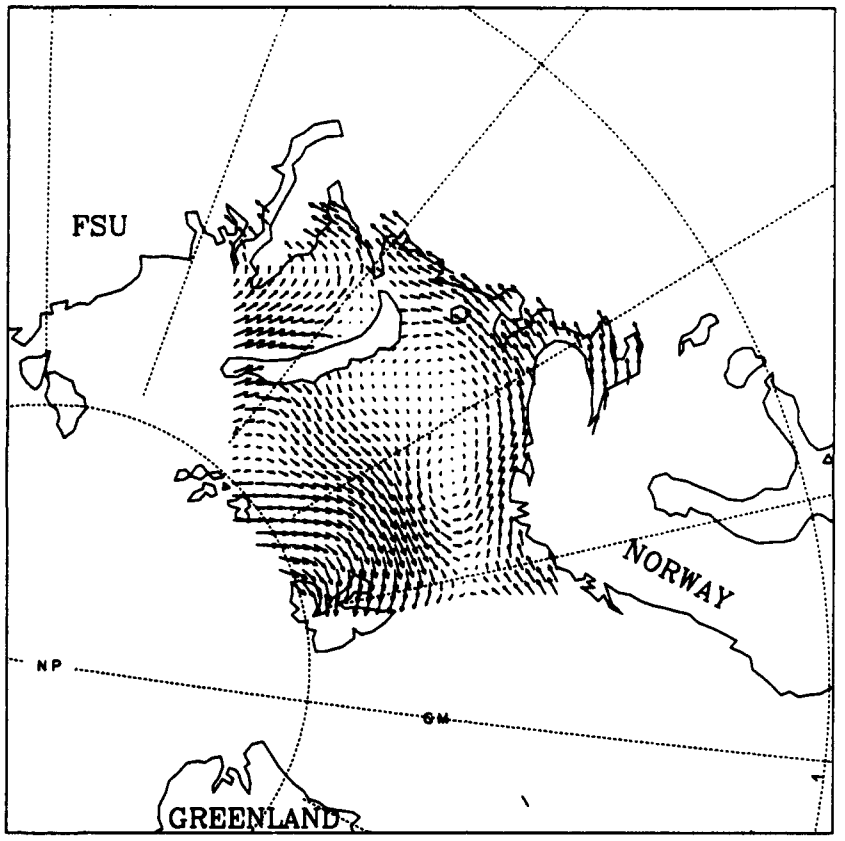


WIND VELOCITIES 1993 MARCH



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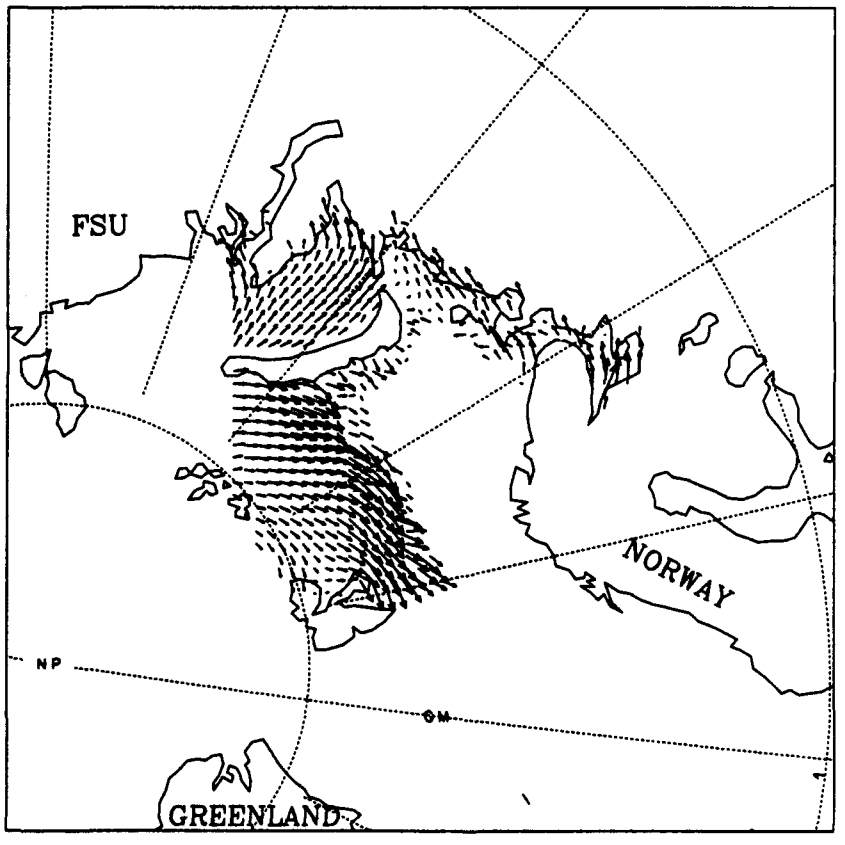

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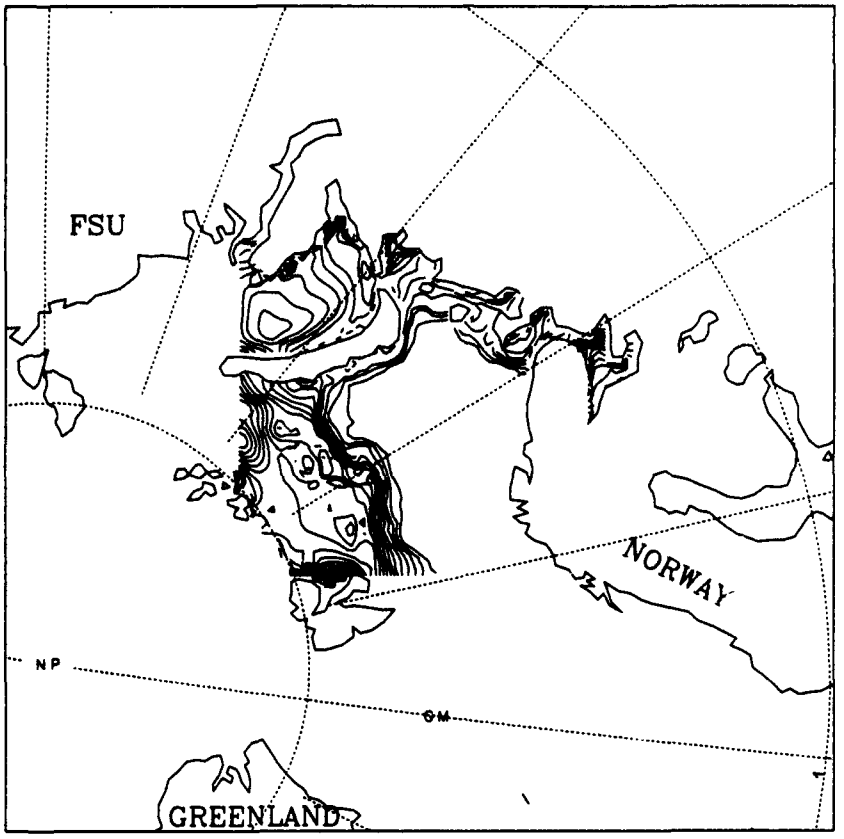

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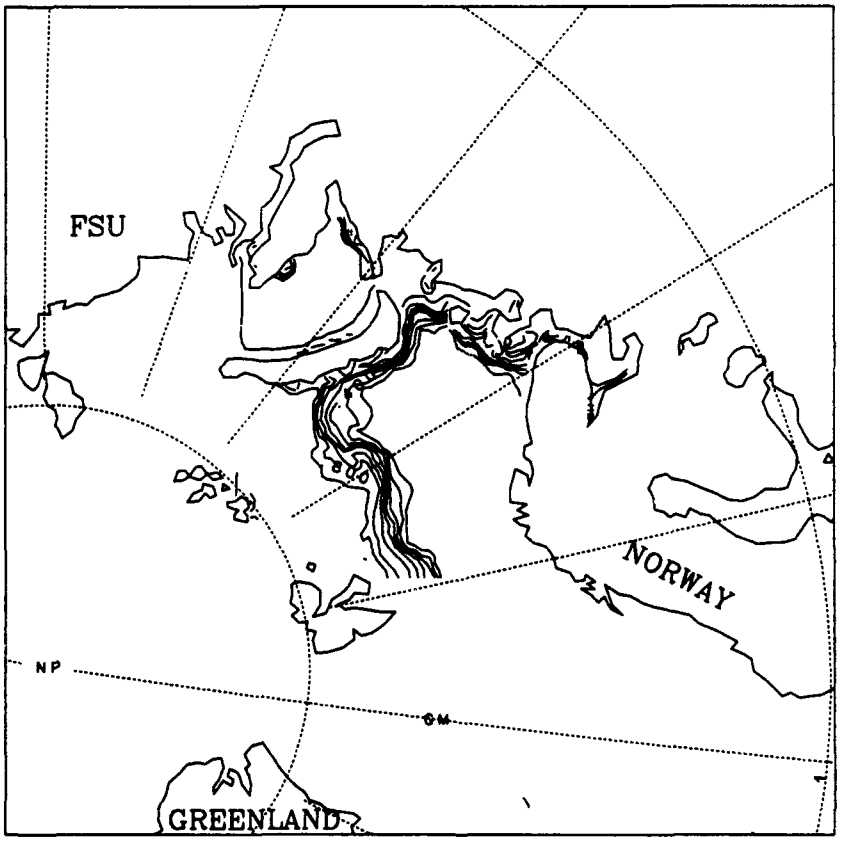
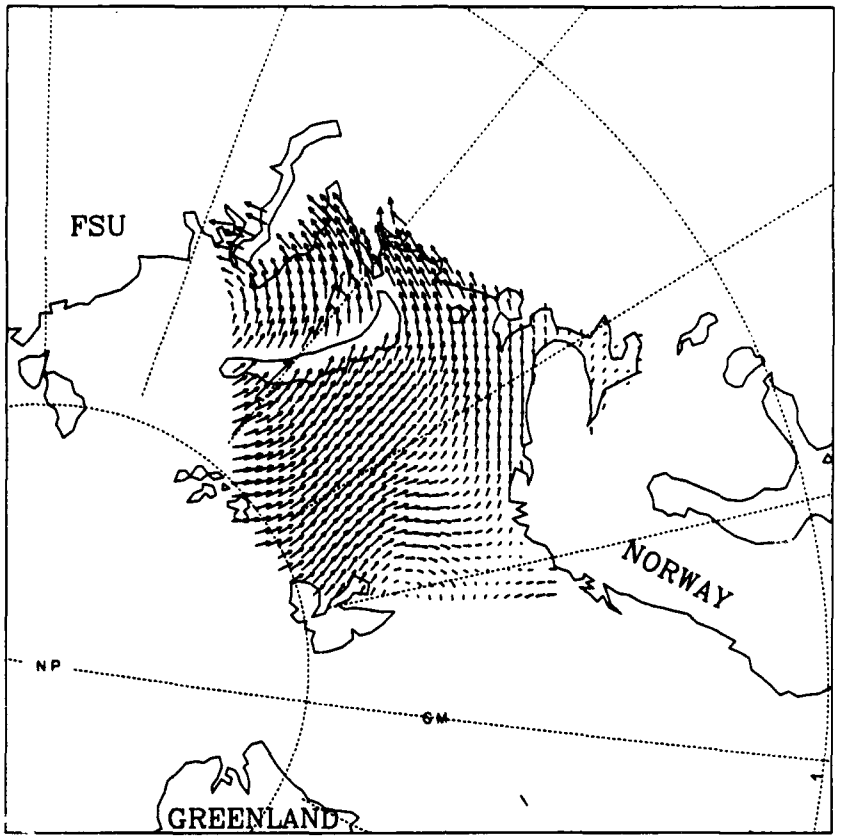
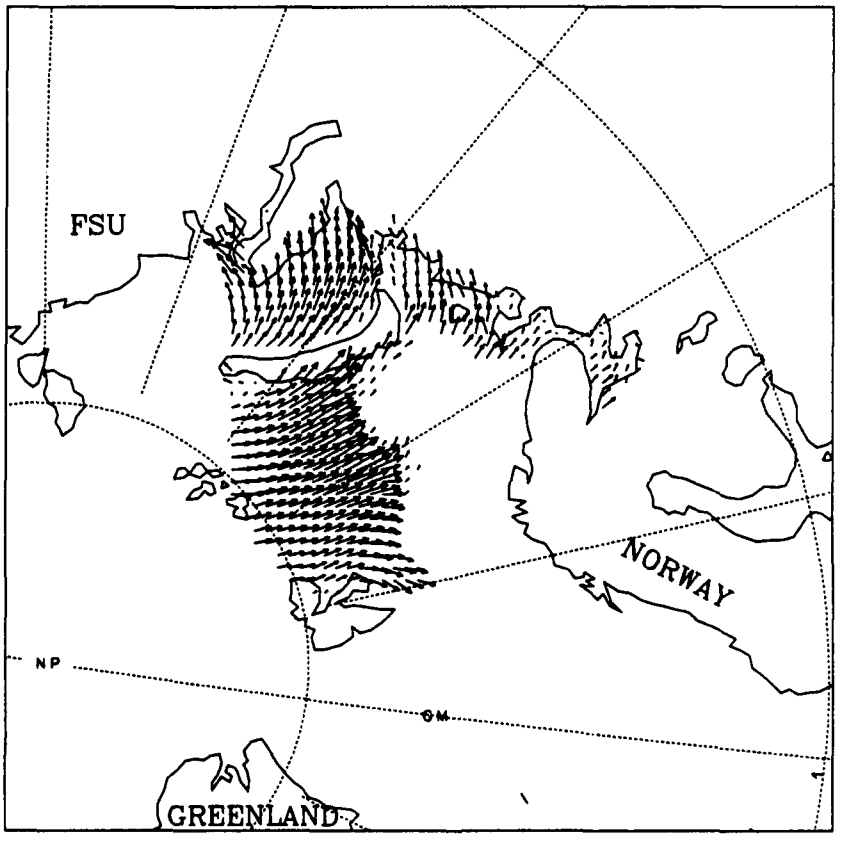


WIND VELOCITIES 1993 APRIL



ICE VELOCITIES 1993 APRIL



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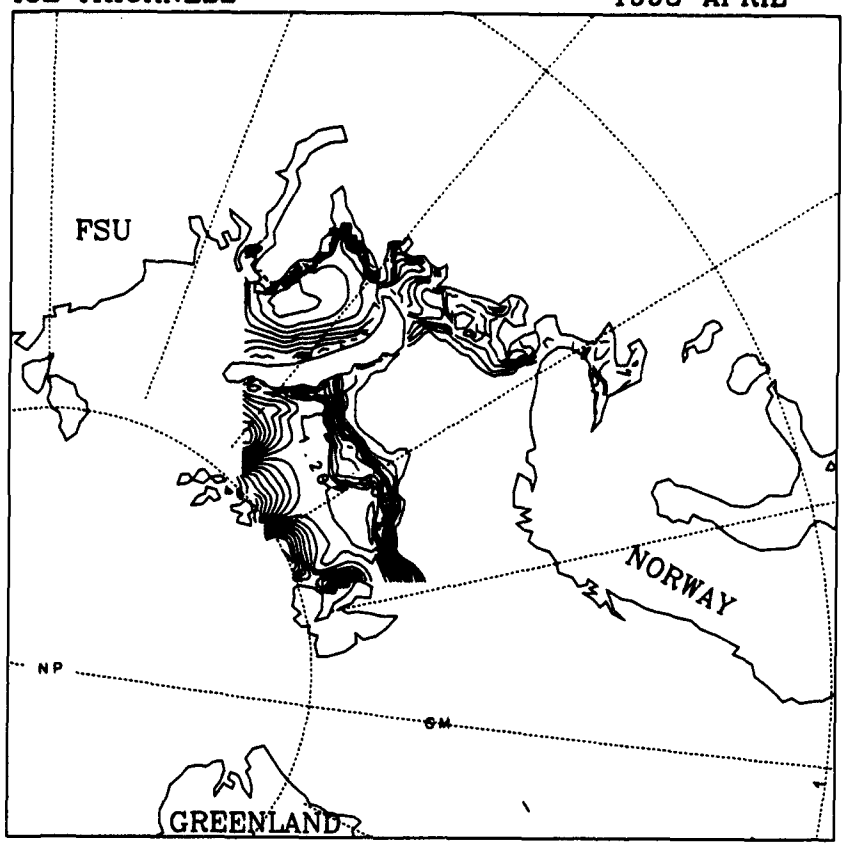

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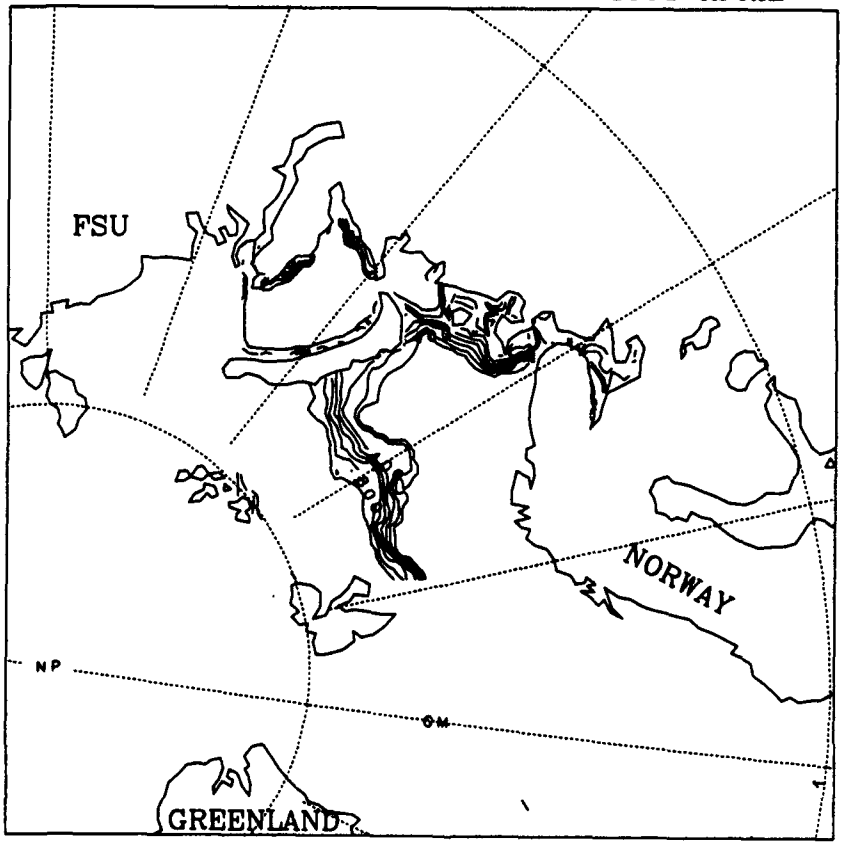

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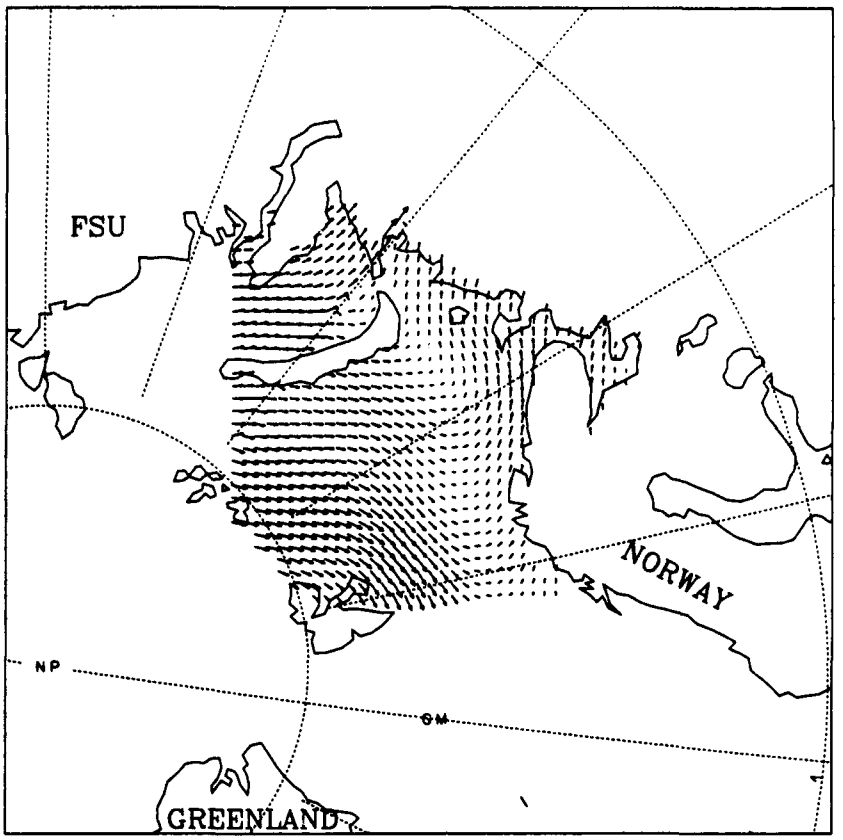

0.300E+02
MAXIMUM VECTOR

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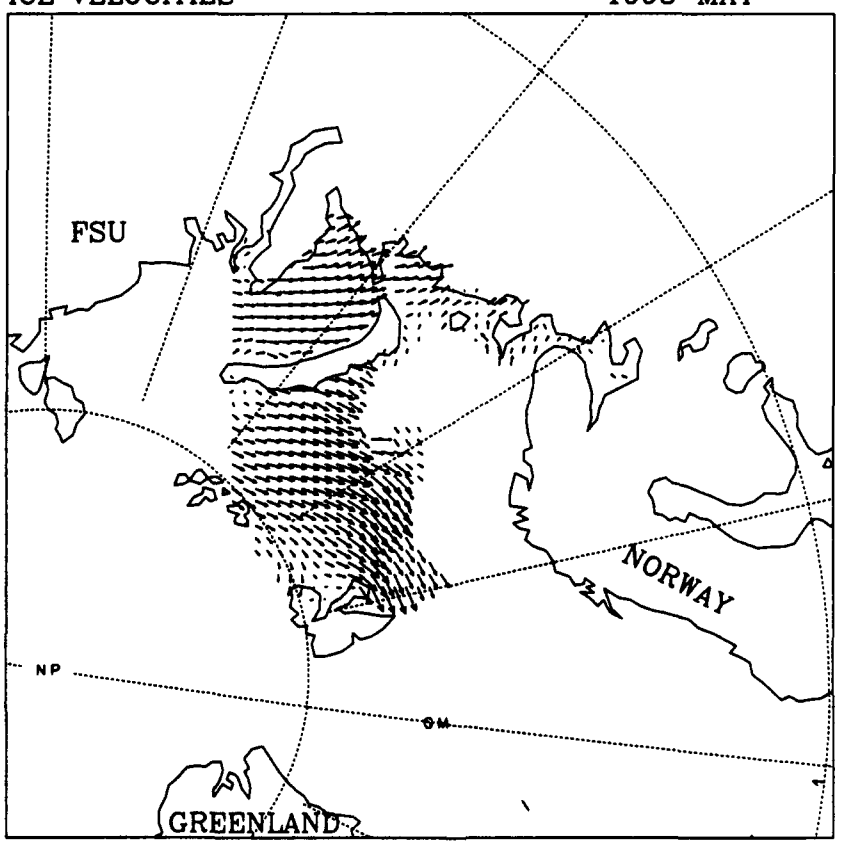

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MAXIMUM VECTOR

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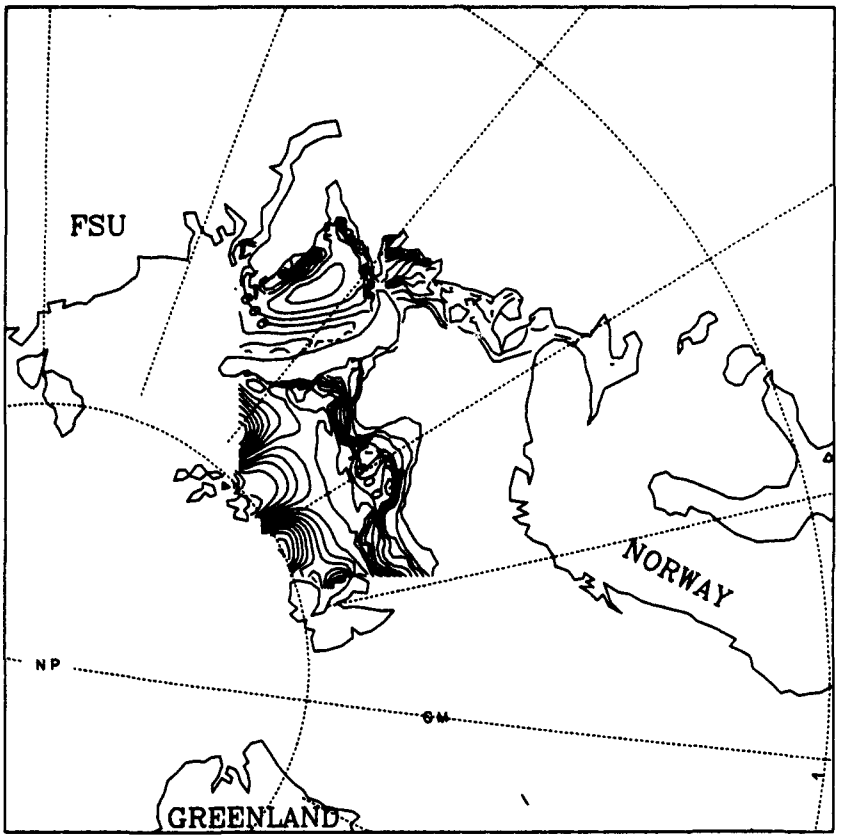

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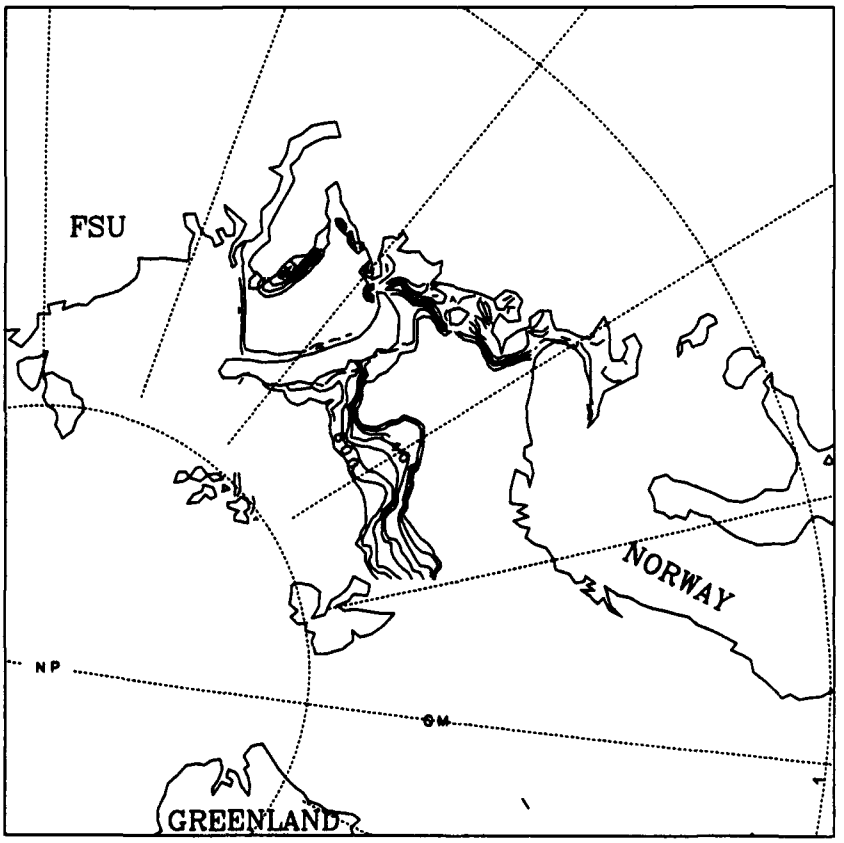
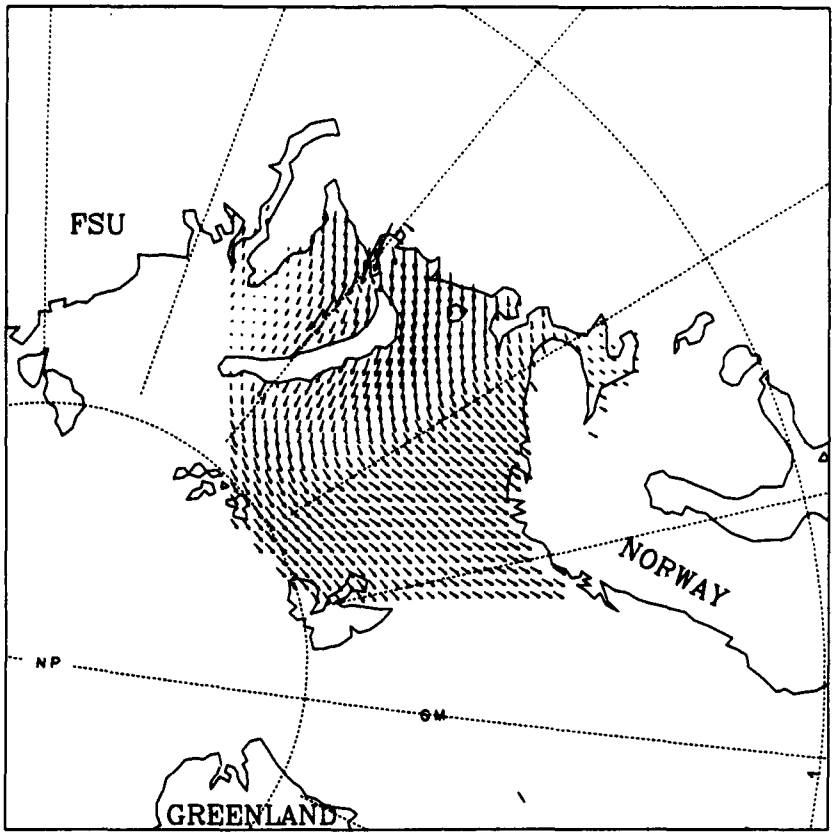


WIND VELOCITIES 1993 JUNE



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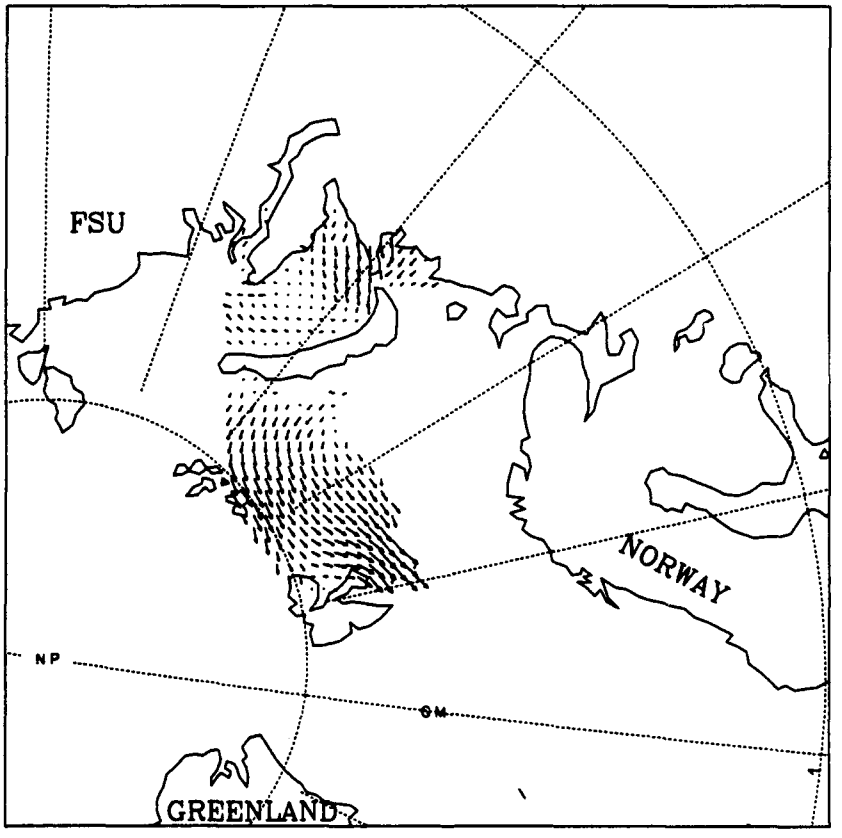

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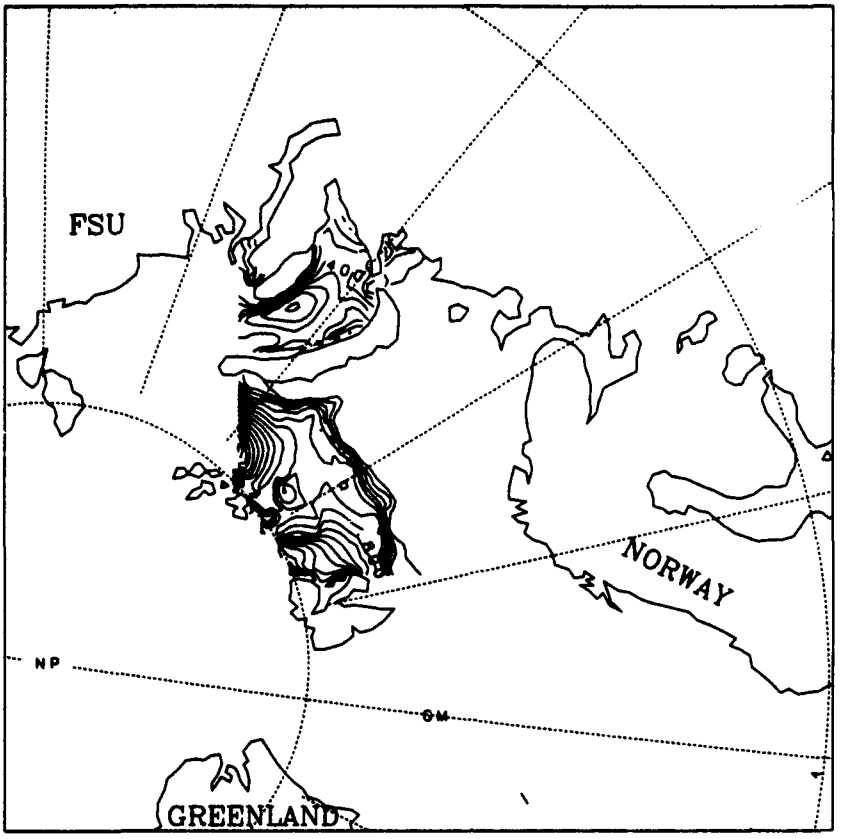
MAXIMUM VECTOR

ICE THICKNESS 1993 JUNE



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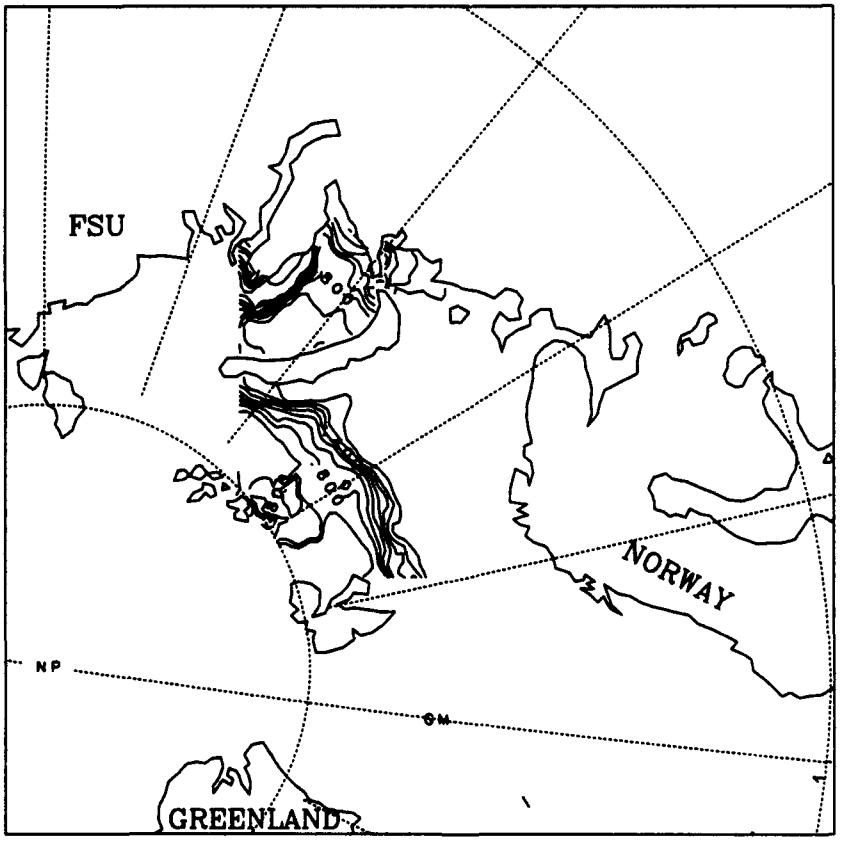
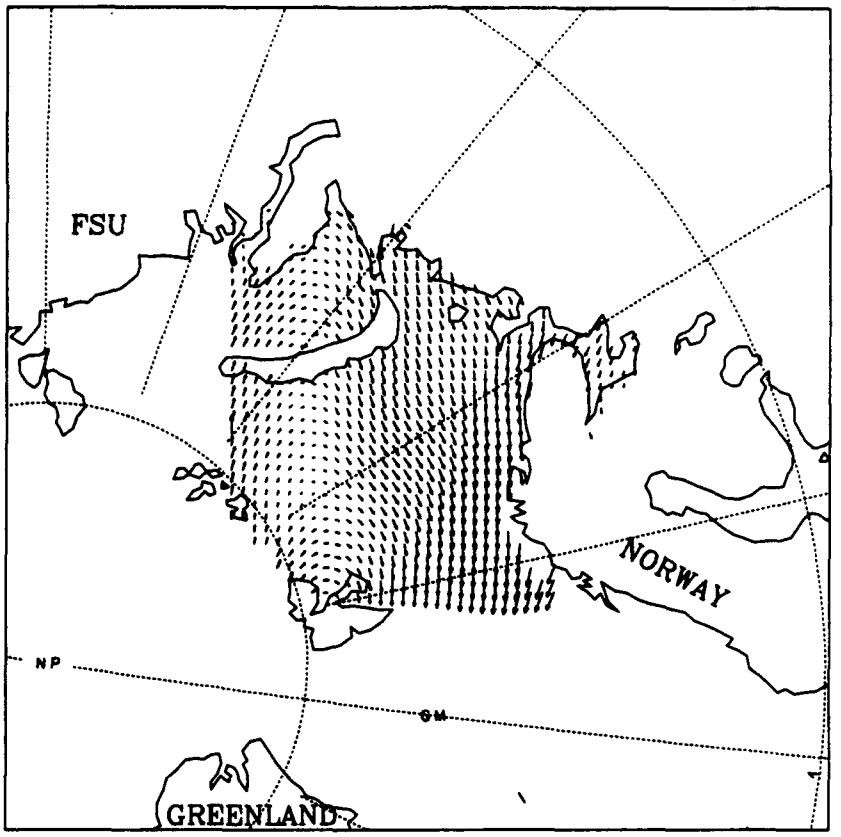


WIND VELOCITIES 1993 JULY



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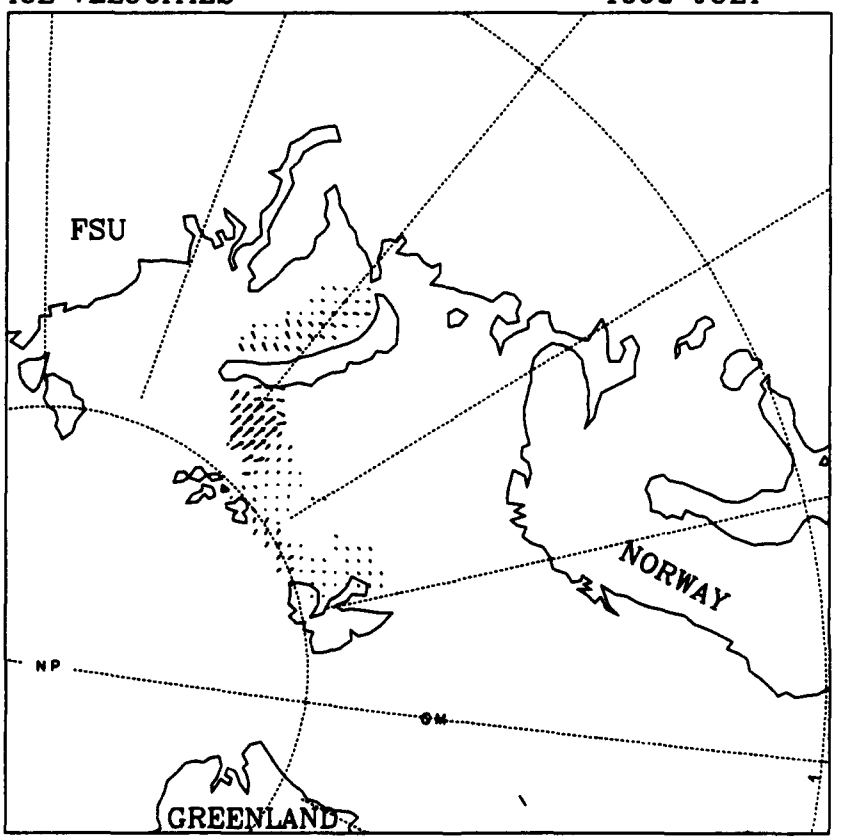
MAXIMUM VECTOR

ICE VELOCITIES 1993 JULY



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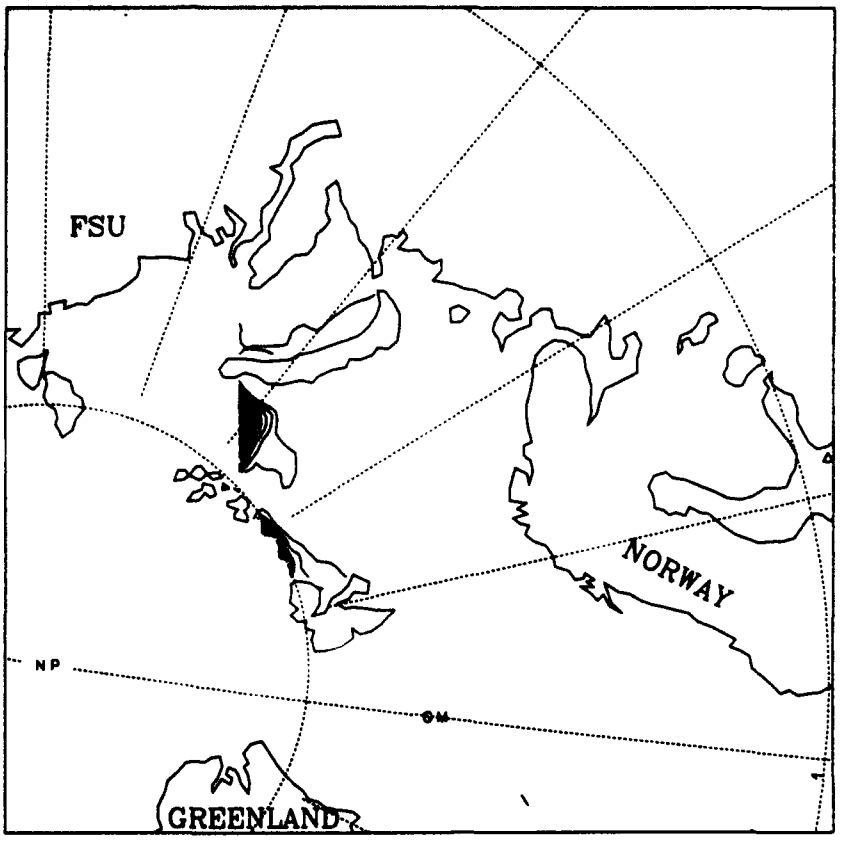
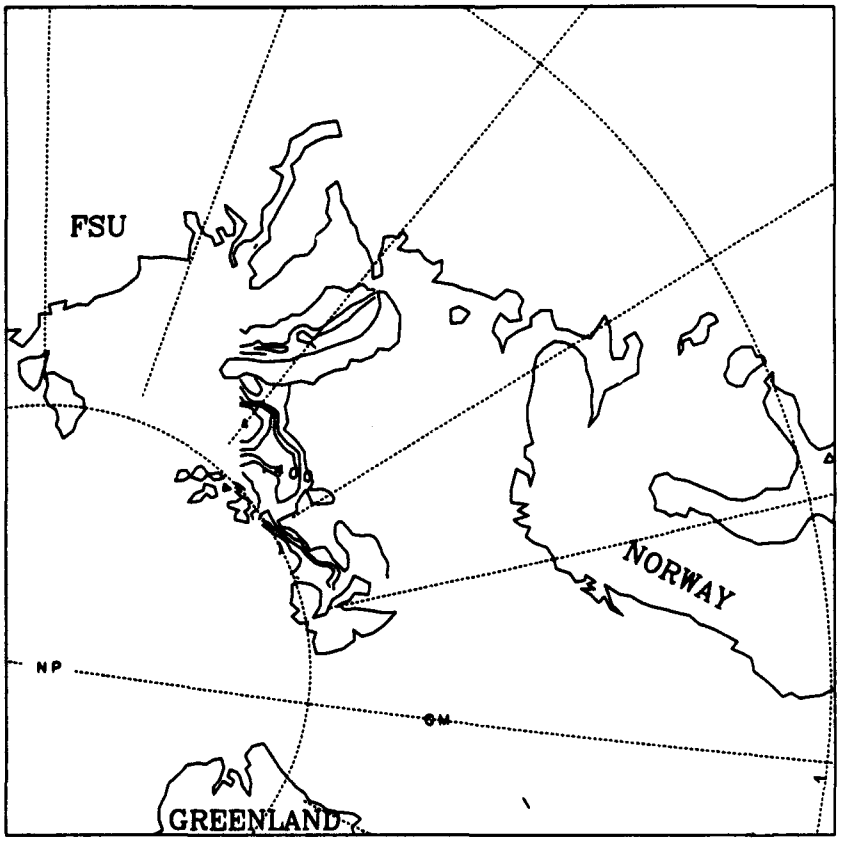
MAXIMUM VECTOR

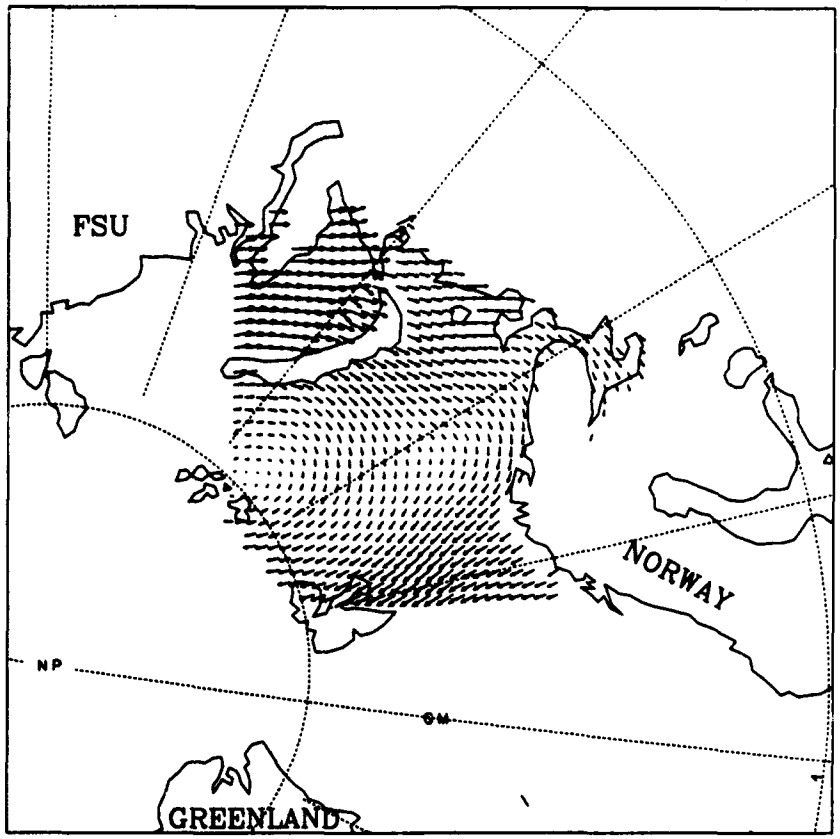
ICE THICKNESS 1993 JULY



ICE CONCENTRATION 1993 JULY



WIND VELOCITIES 1993 AUGUST



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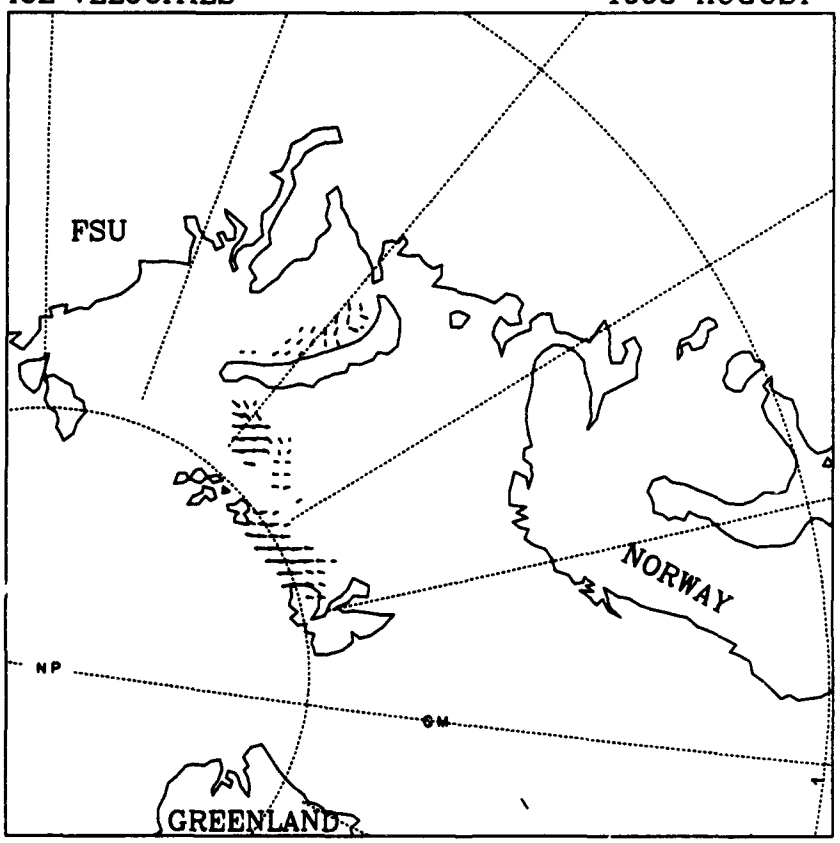
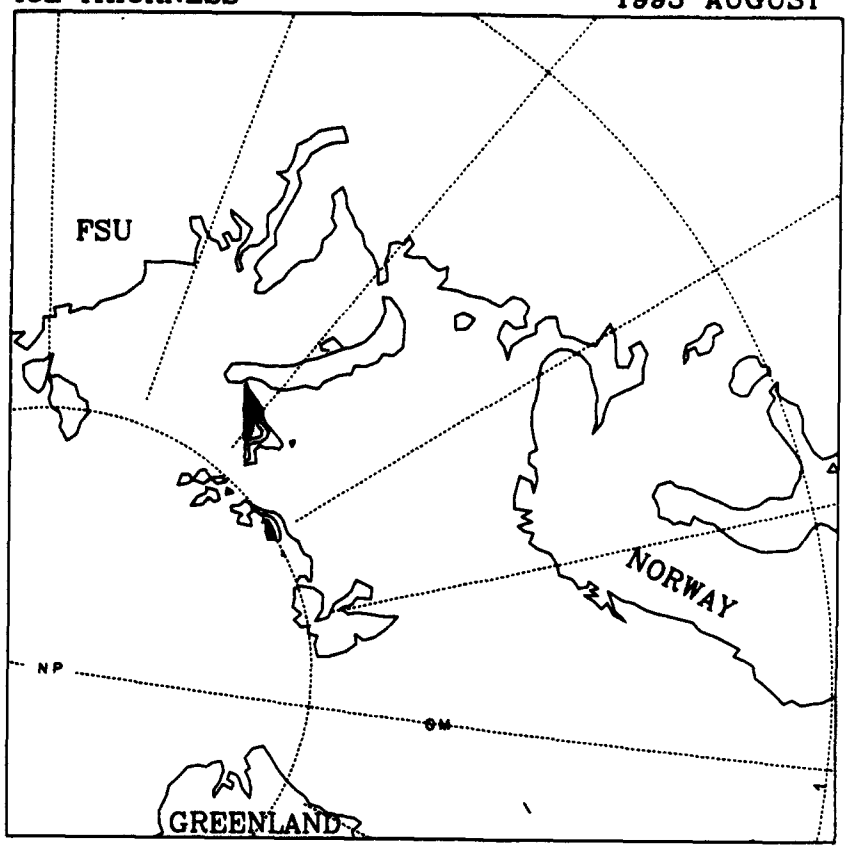


ICE THICKNESS 1993 AUGUST



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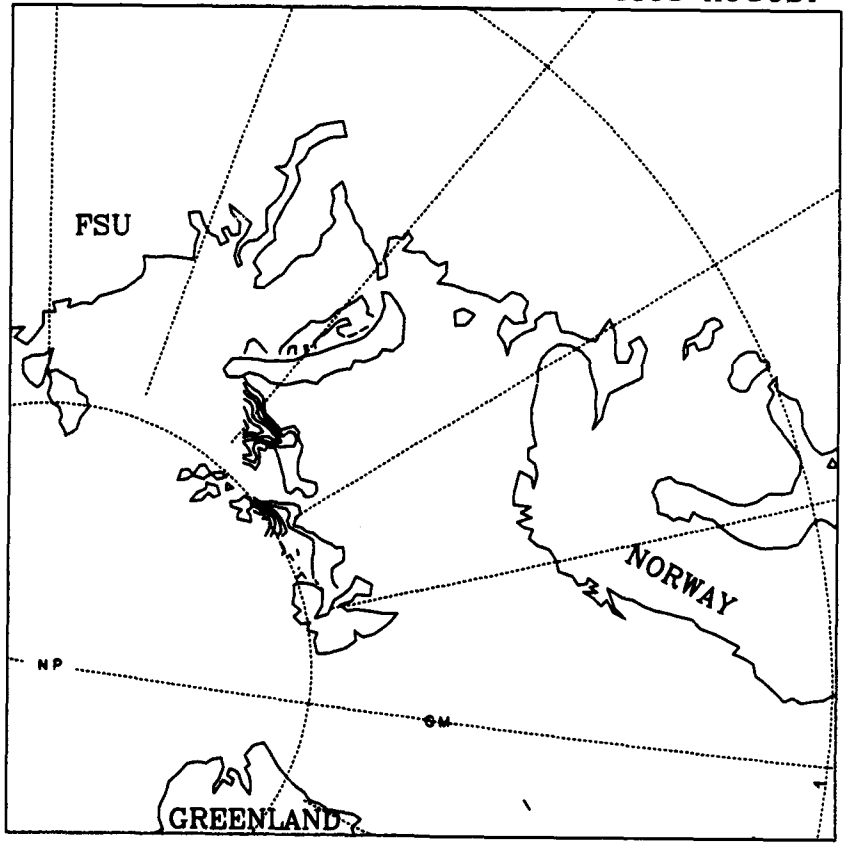
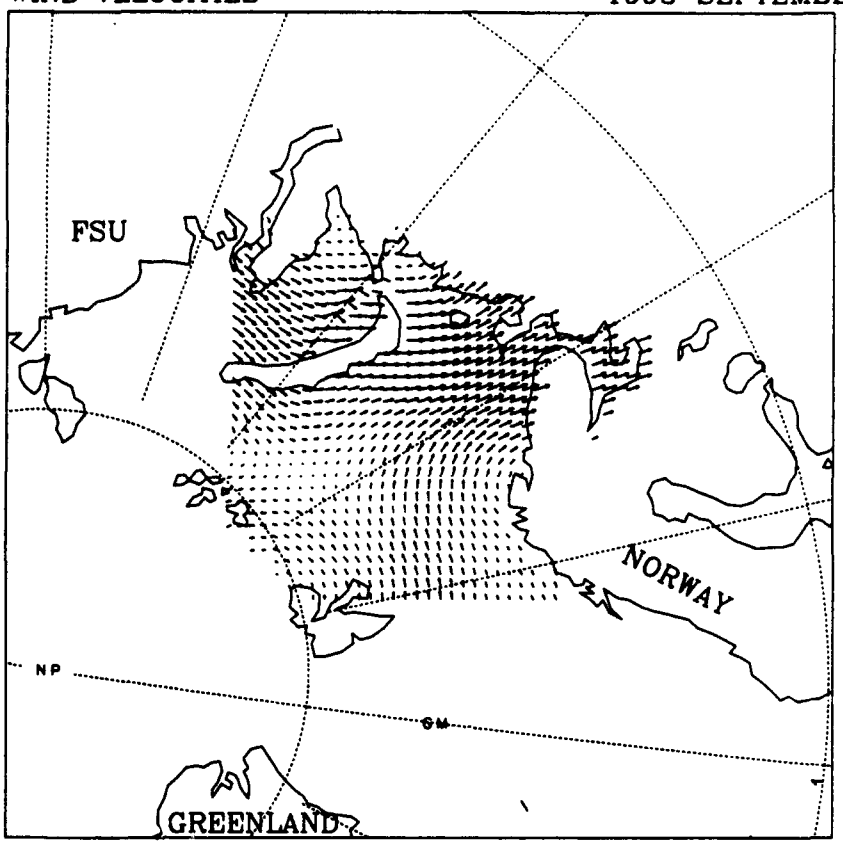
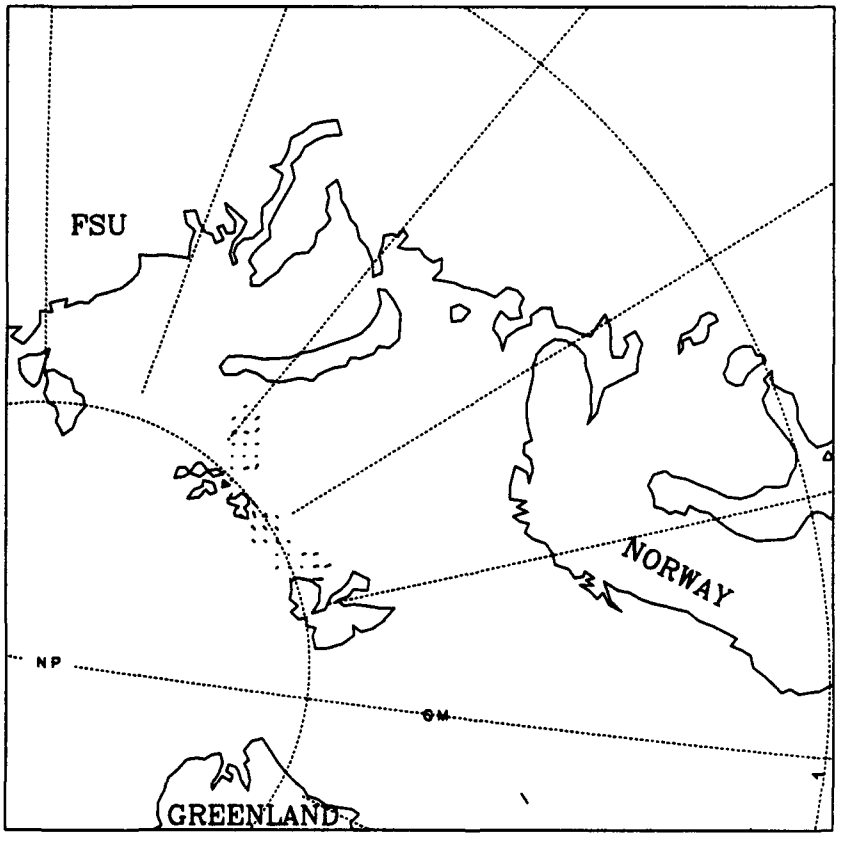


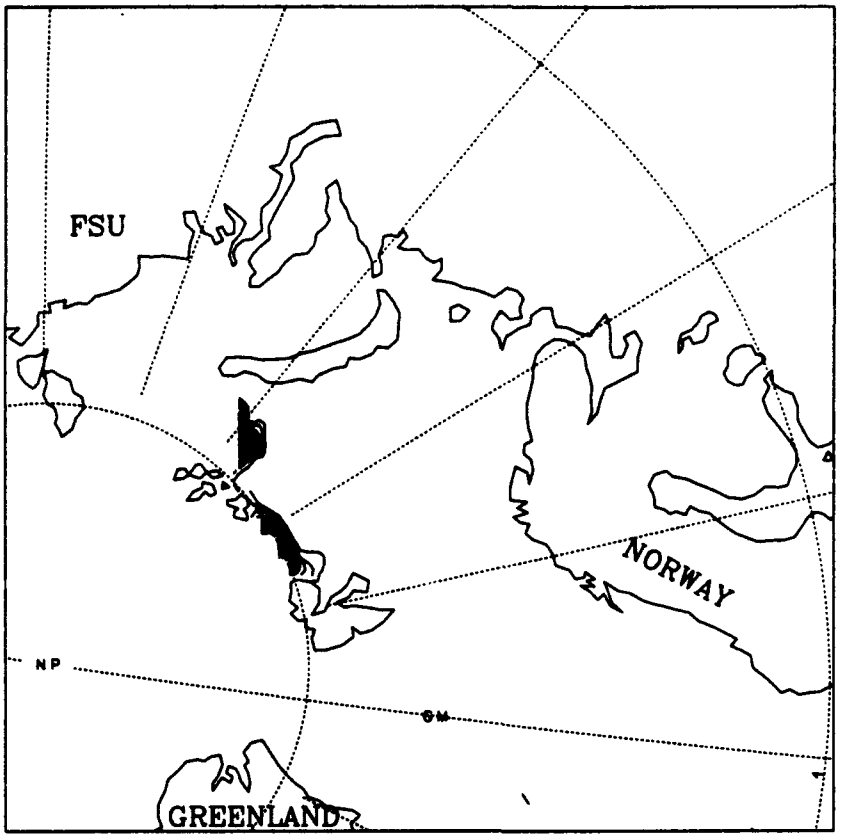
WIND VELOCITIES 1993 SEPTEMBER



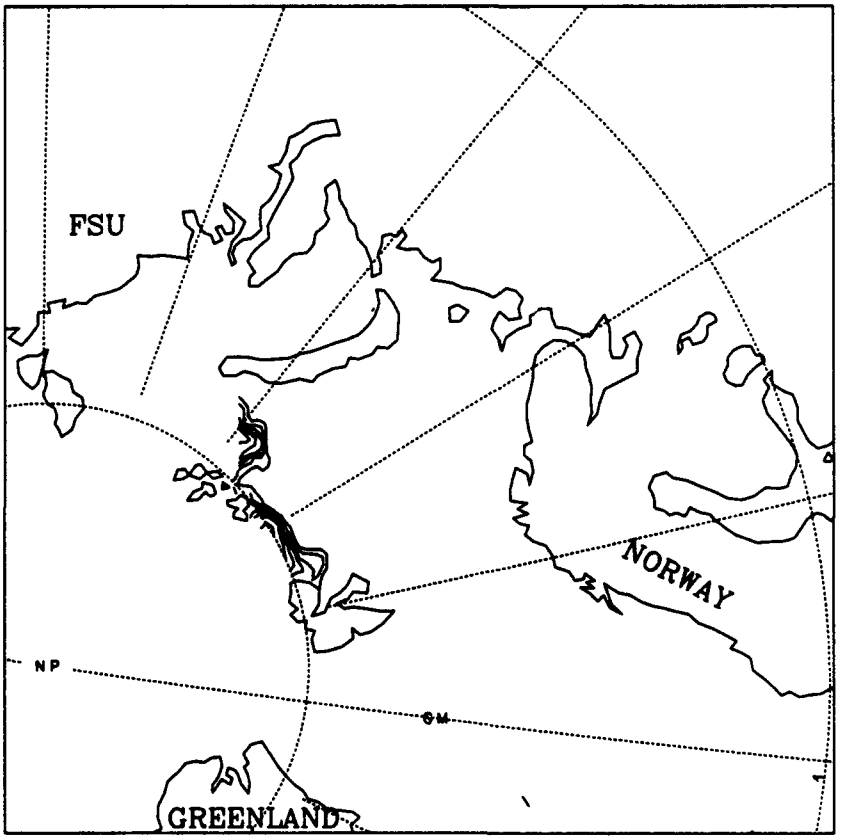
ICE VELOCITIES 1993 SEPTEMBER



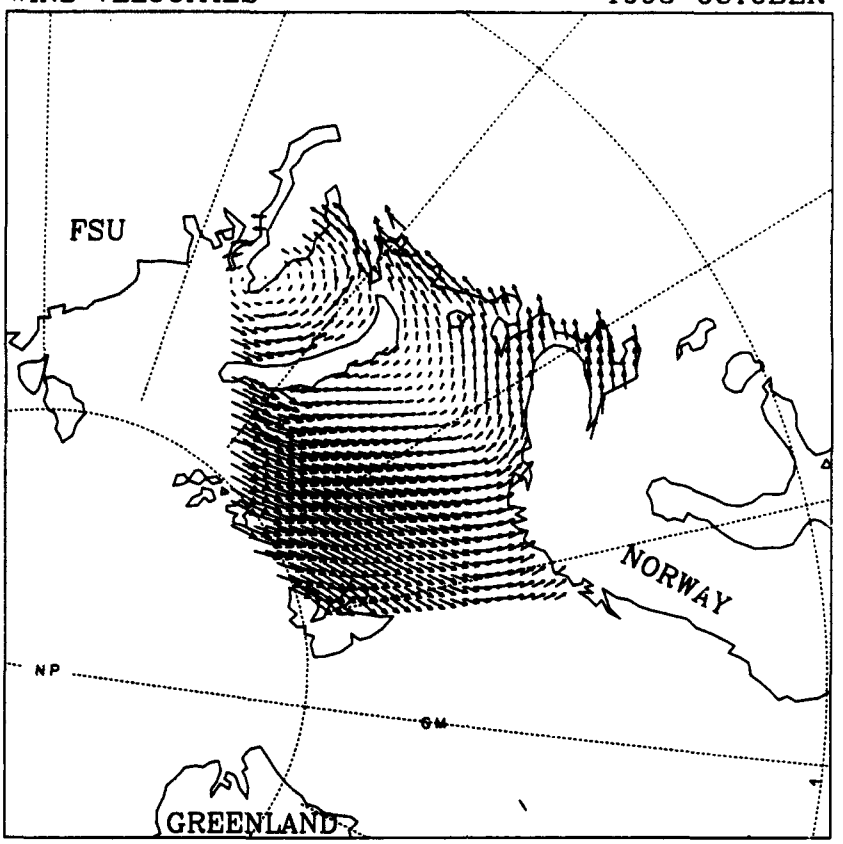
ICE THICKNESS 1993 SEPTEMBER



ICE CONCENTRATION 1993 SEPTEMBER



WIND VELOCITIES 1993 OCTOBER



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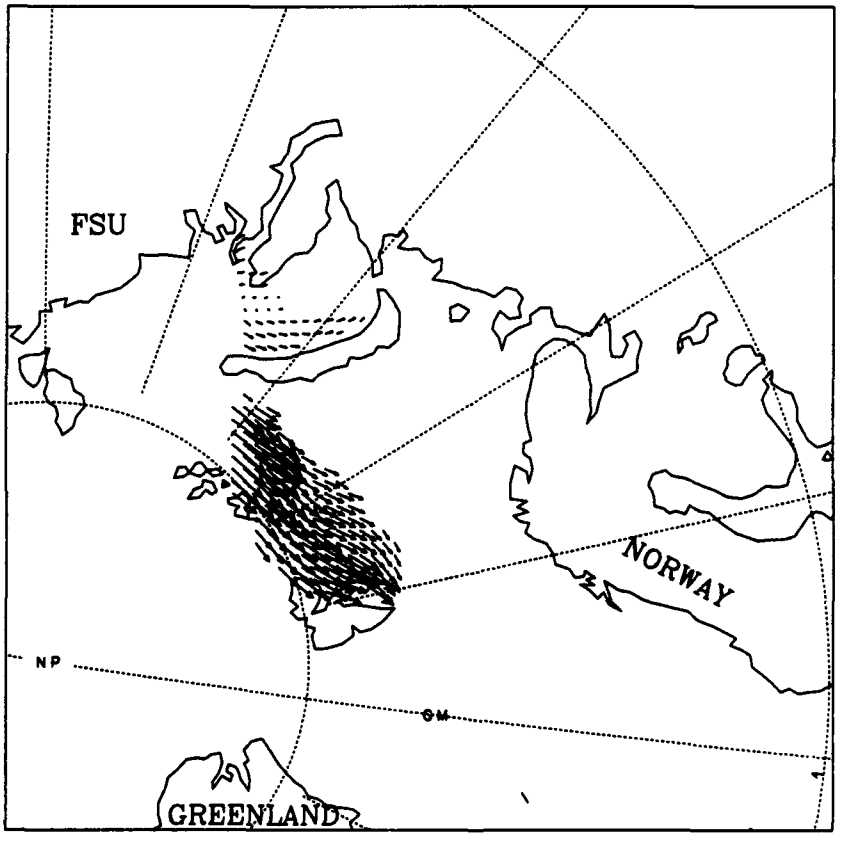

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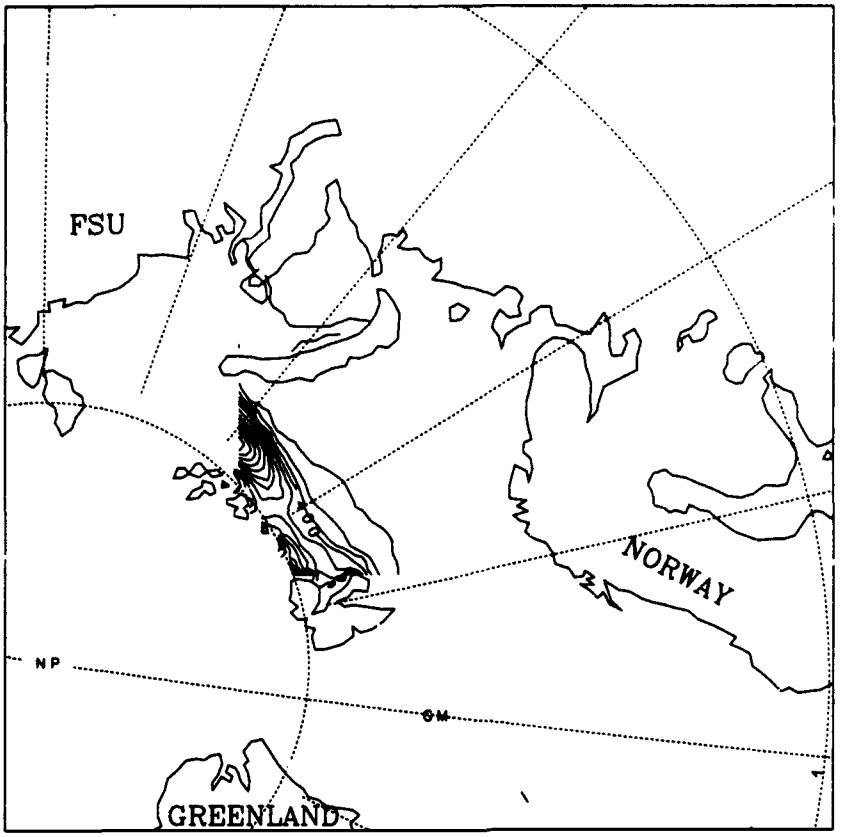

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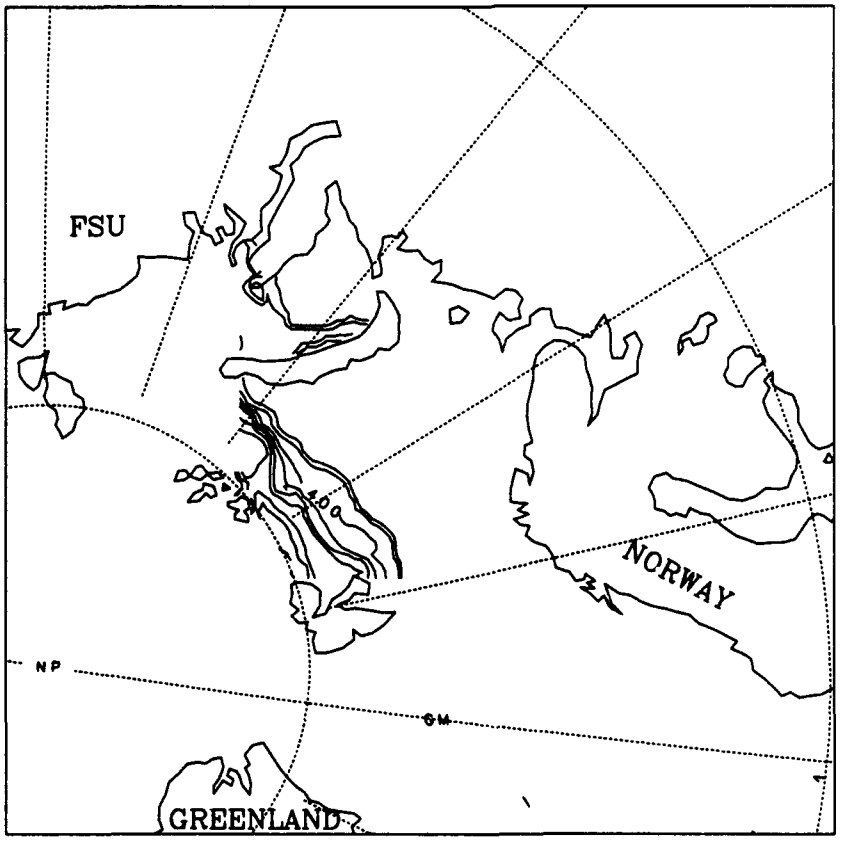
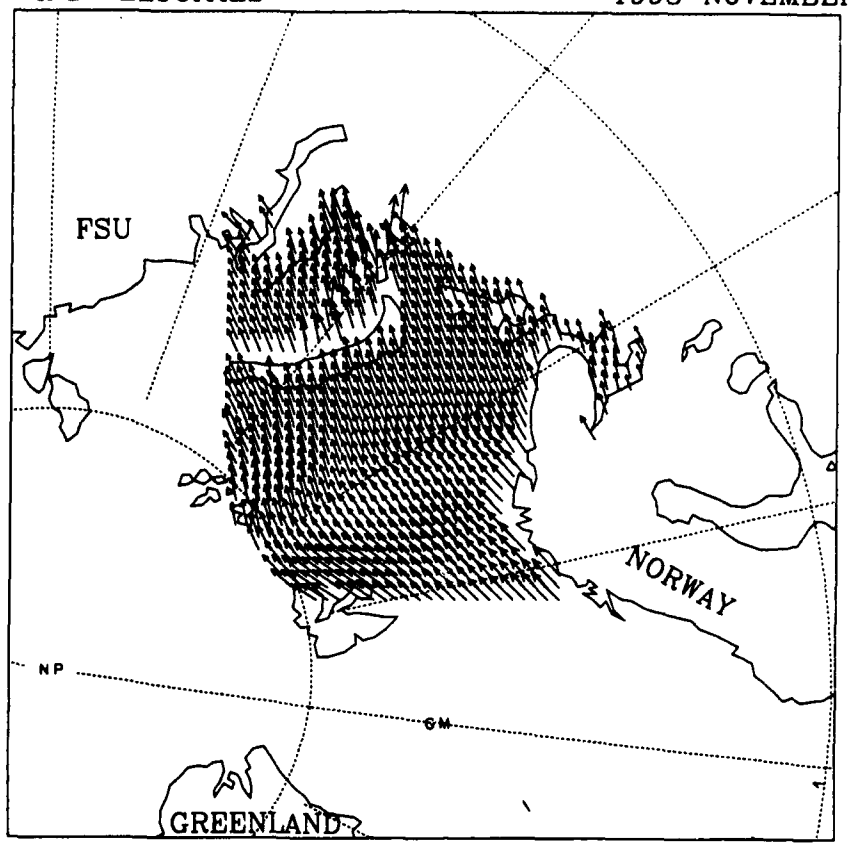


WIND VELOCITIES 1993 NOVEMBER



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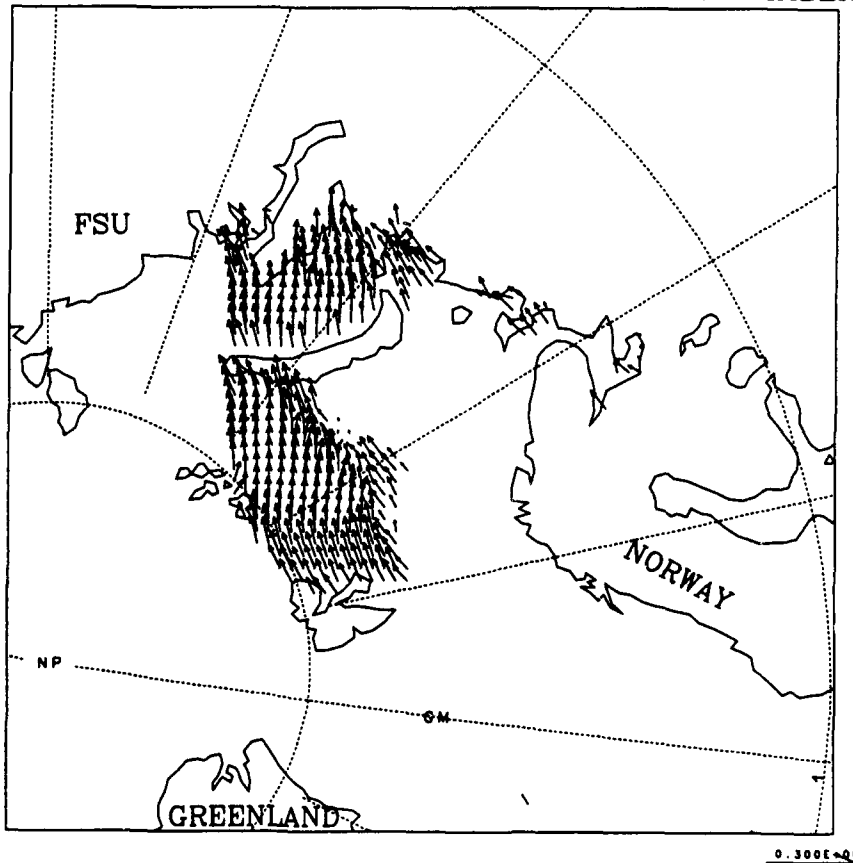
MAXIMUM VECTOR

ICE VELOCITIES 1993 NOVEMBER



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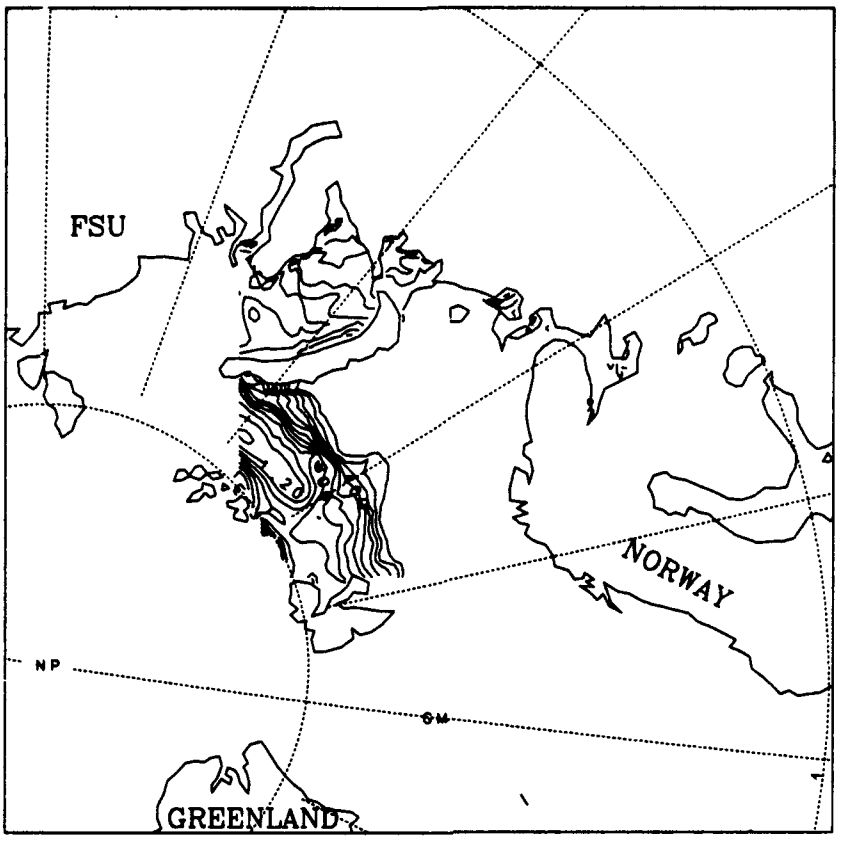

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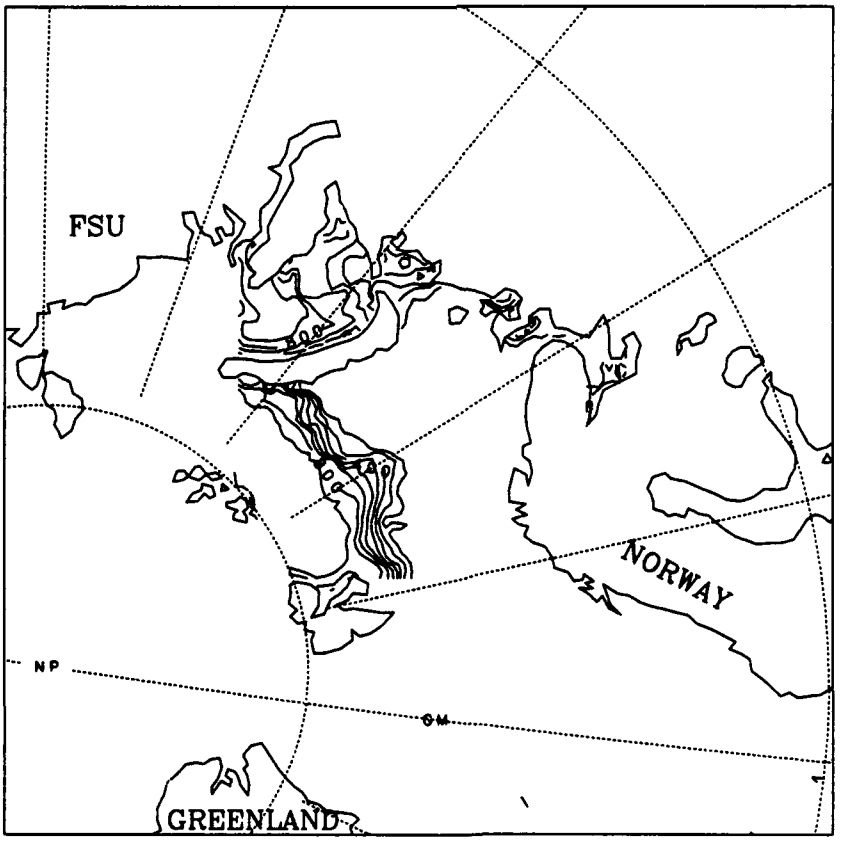

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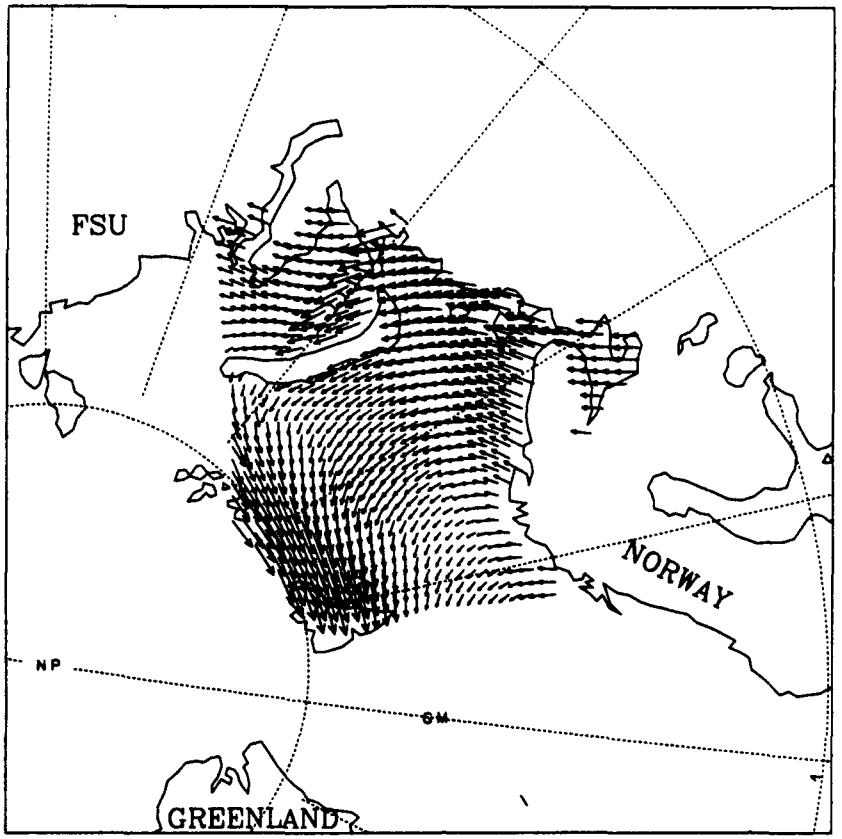

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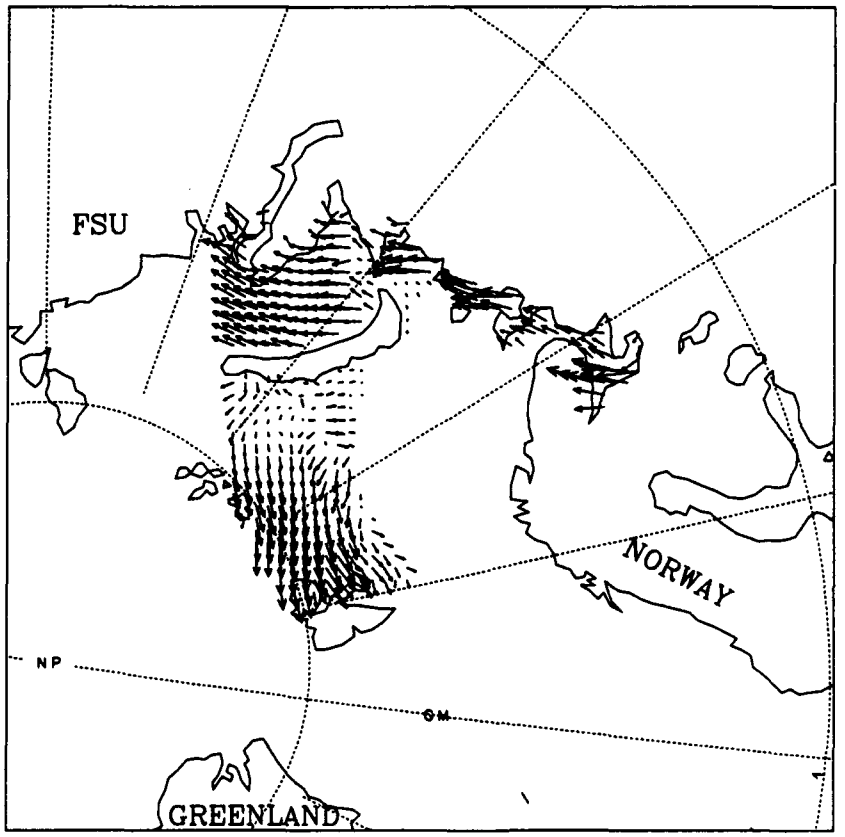

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MAXIMUM VECTOR

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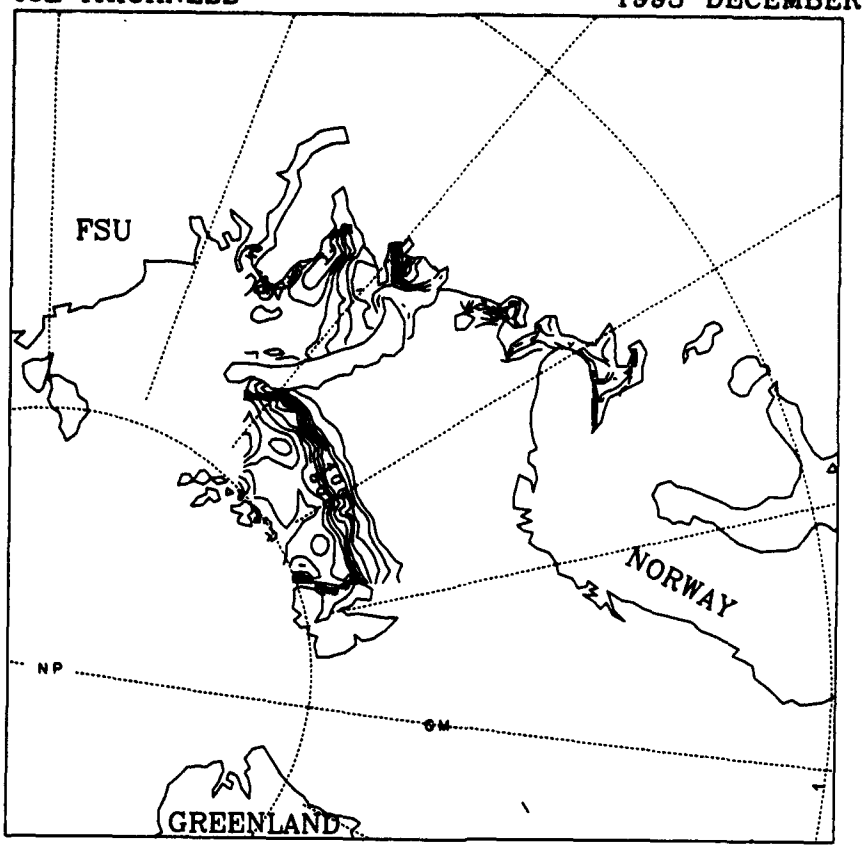

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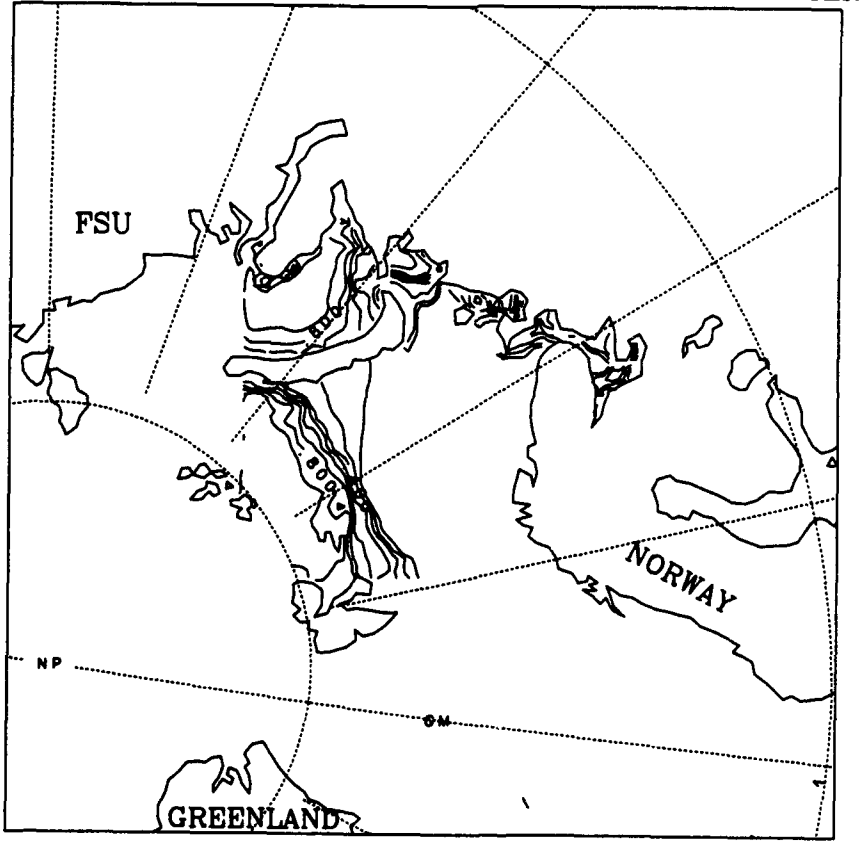


RPIPS-G MODEL GRID

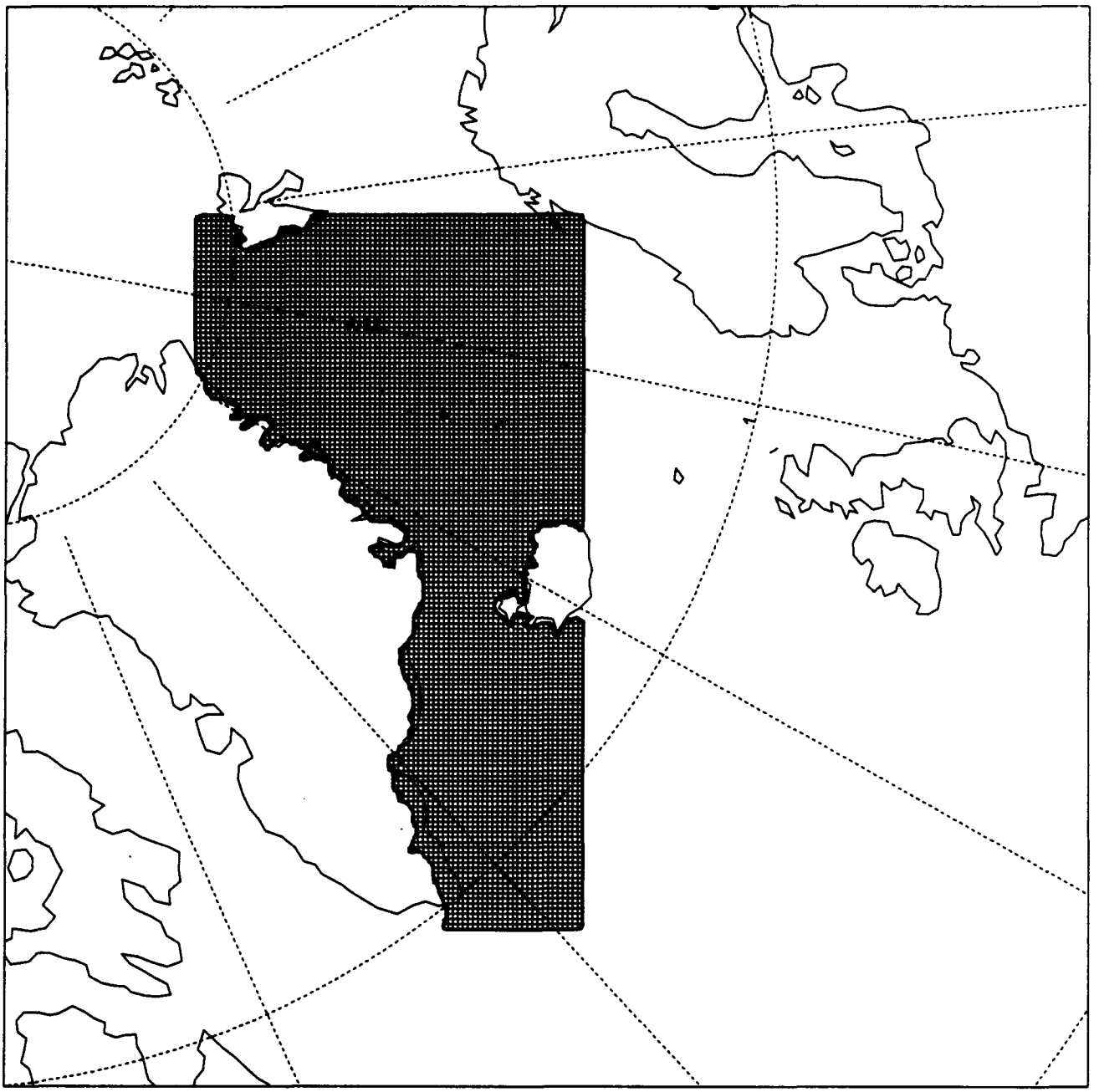
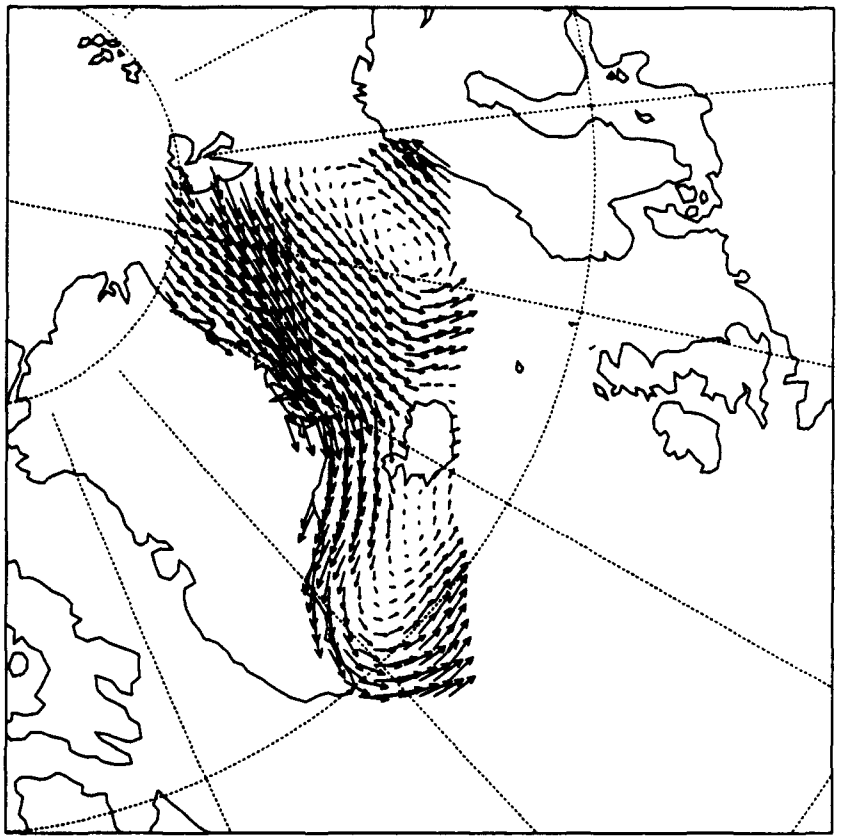


Figure 3. RPIPS-G domain with the 20-km resolution grid overlaid.

RPIPS-G 1993

MONTHLY MEANS

WIND VELOCITIES 1993 JANUARY



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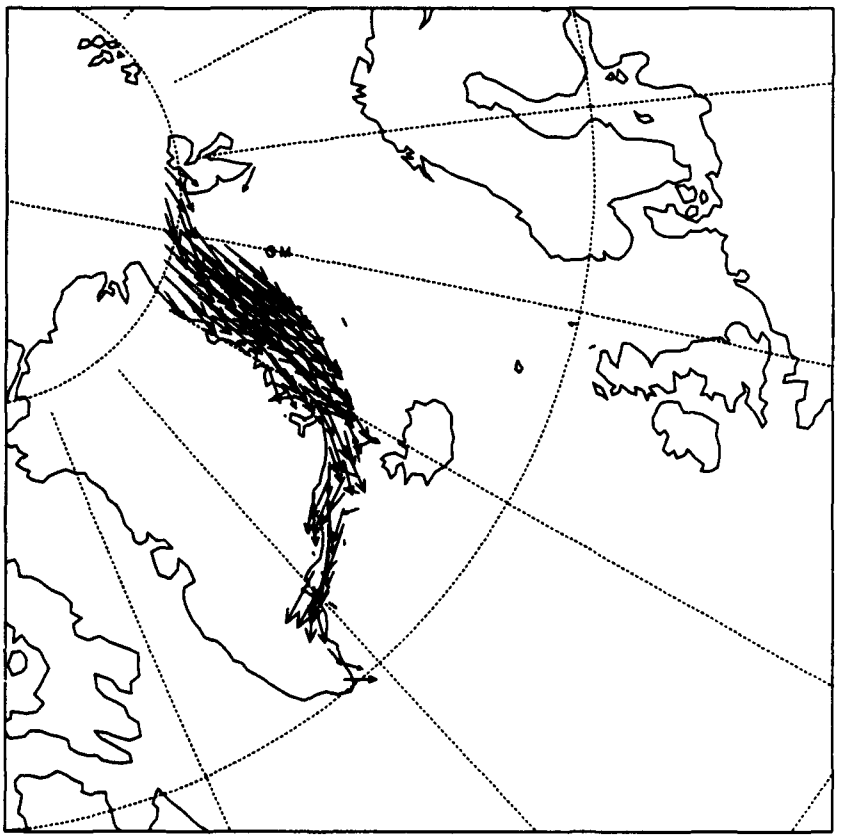
MAXIMUM VECTOR

ICE VELOCITIES 1993 JANUARY



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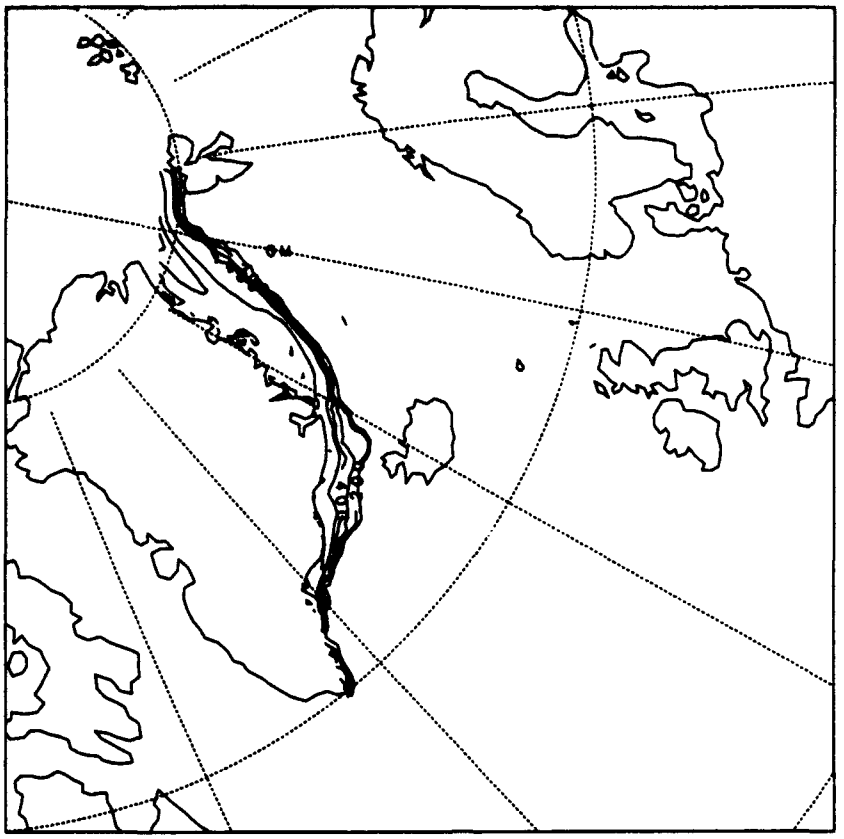
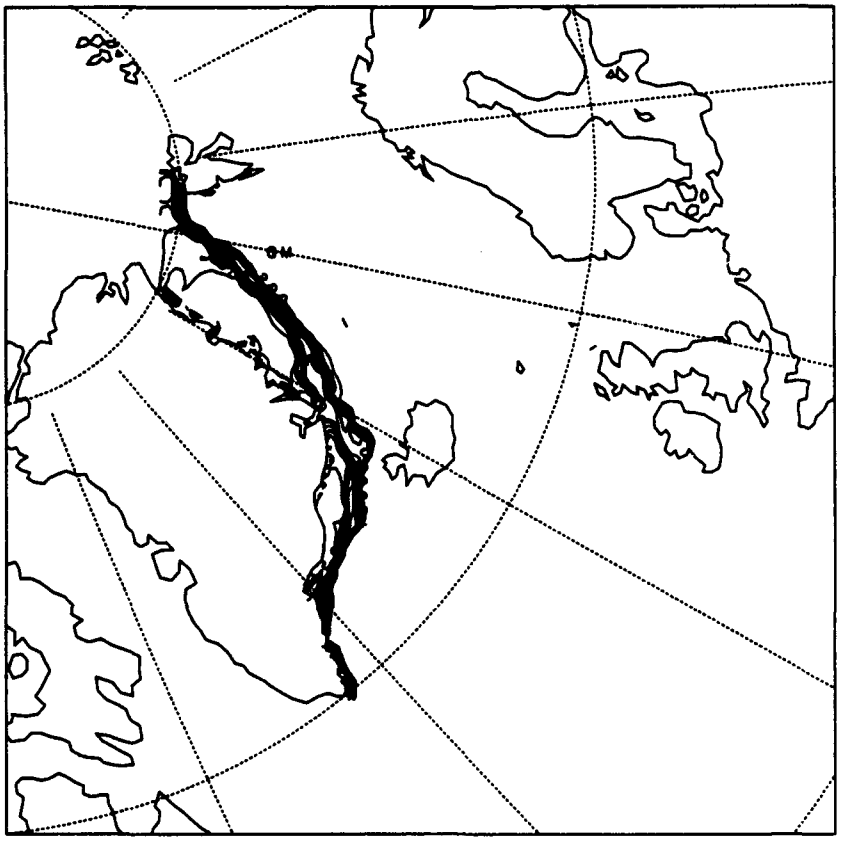
MAXIMUM VECTOR

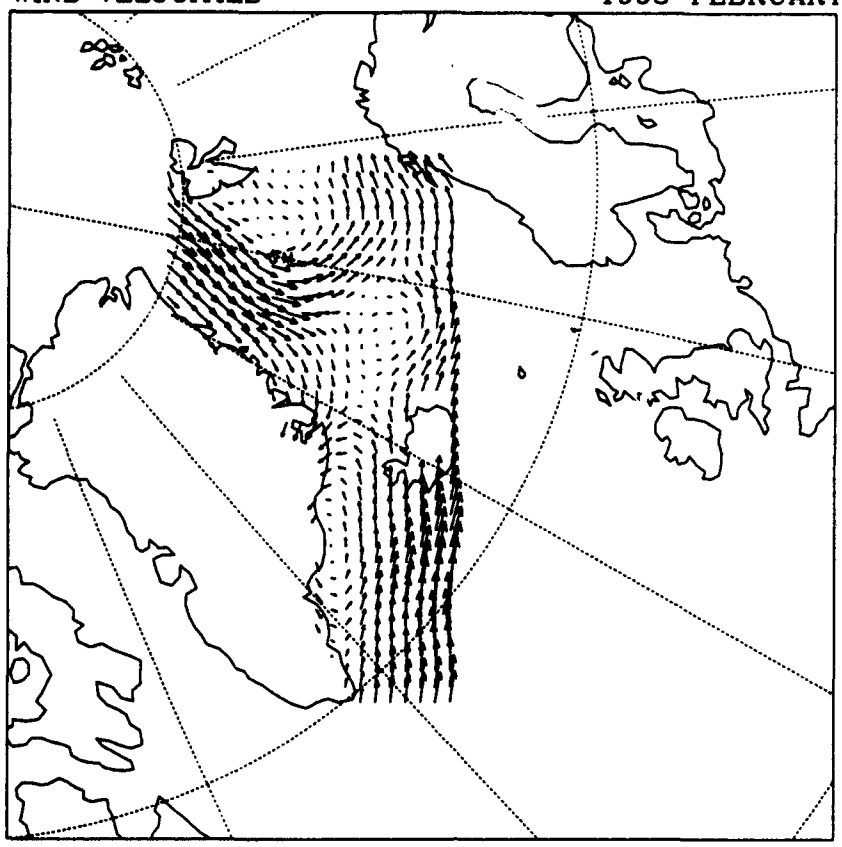
ICE THICKNESS 1993 JANUARY



ICE CONCENTRATION 1993 JANUARY



WIND VELOCITIES 1993 FEBRUARY



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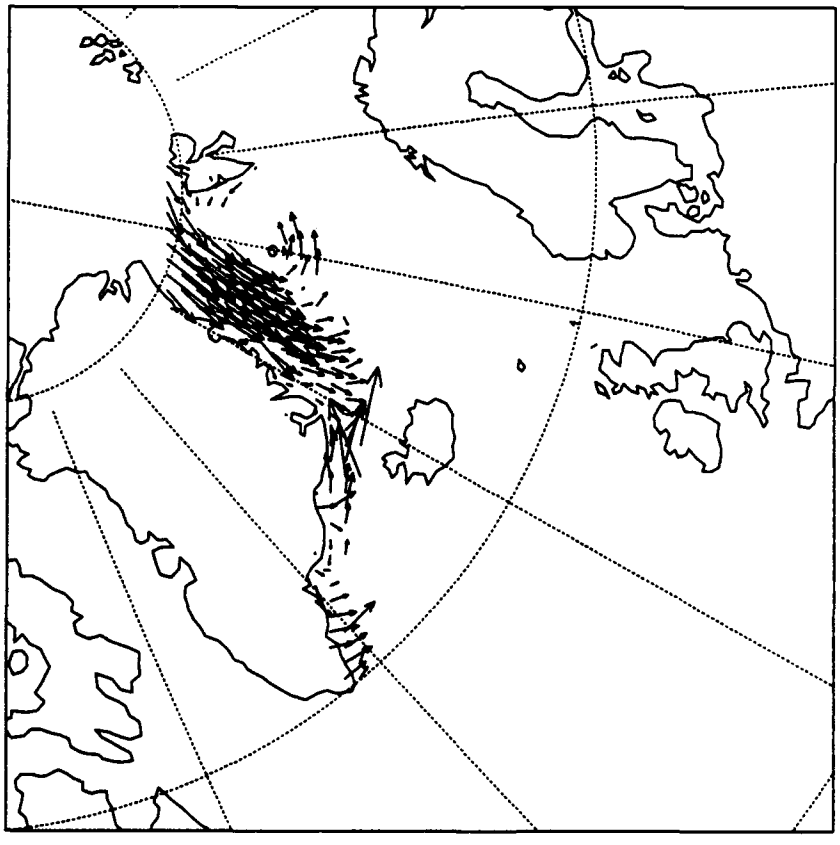

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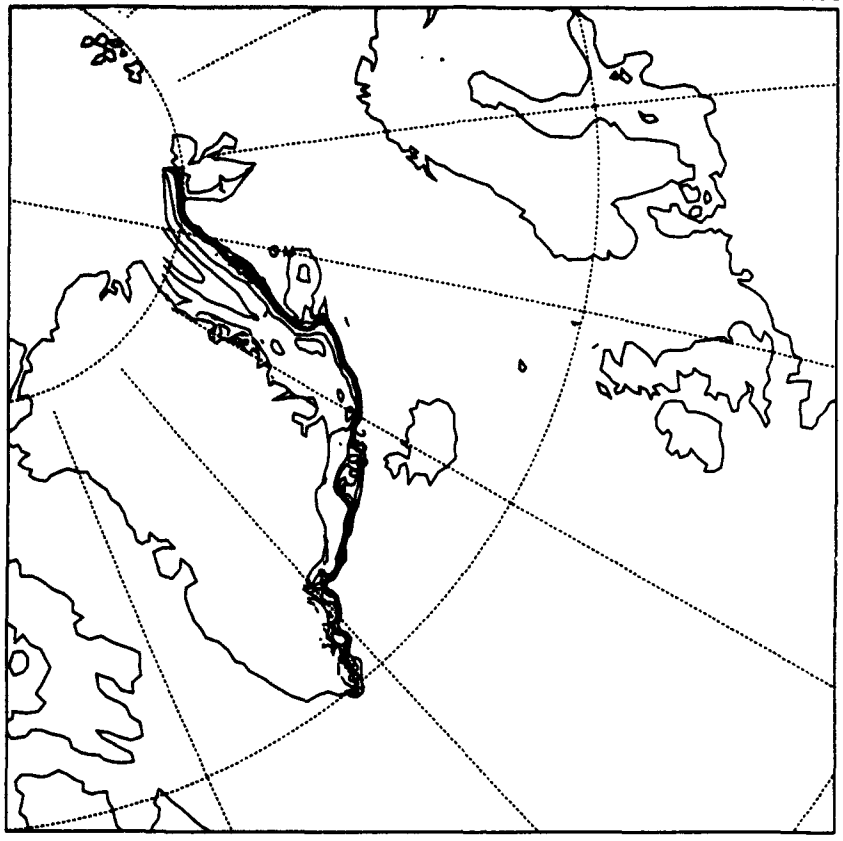

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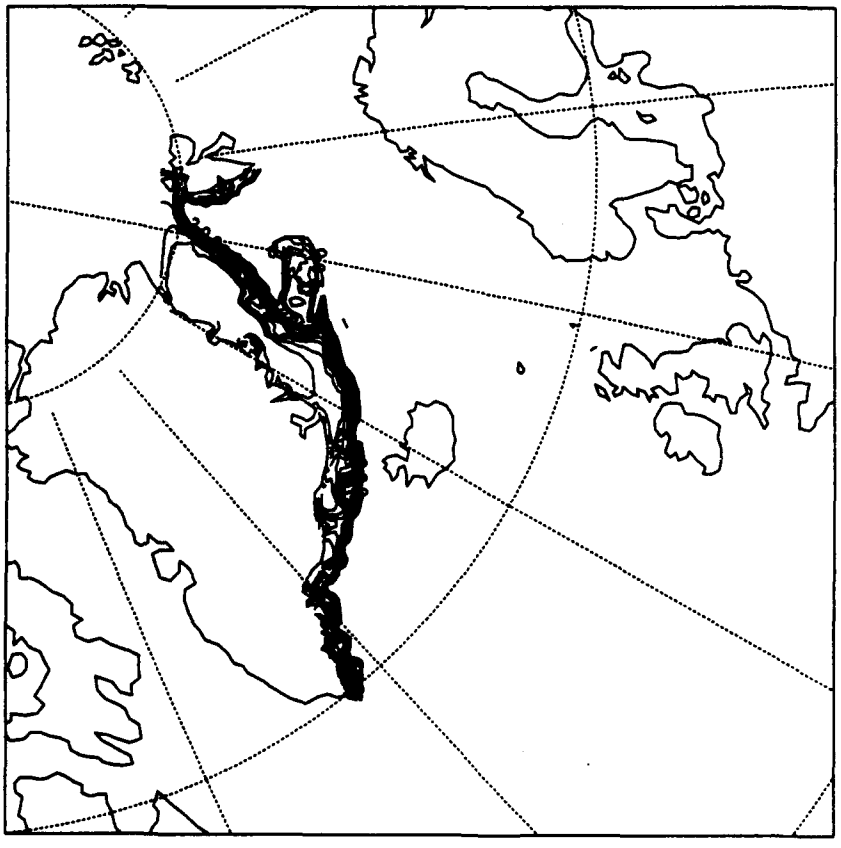
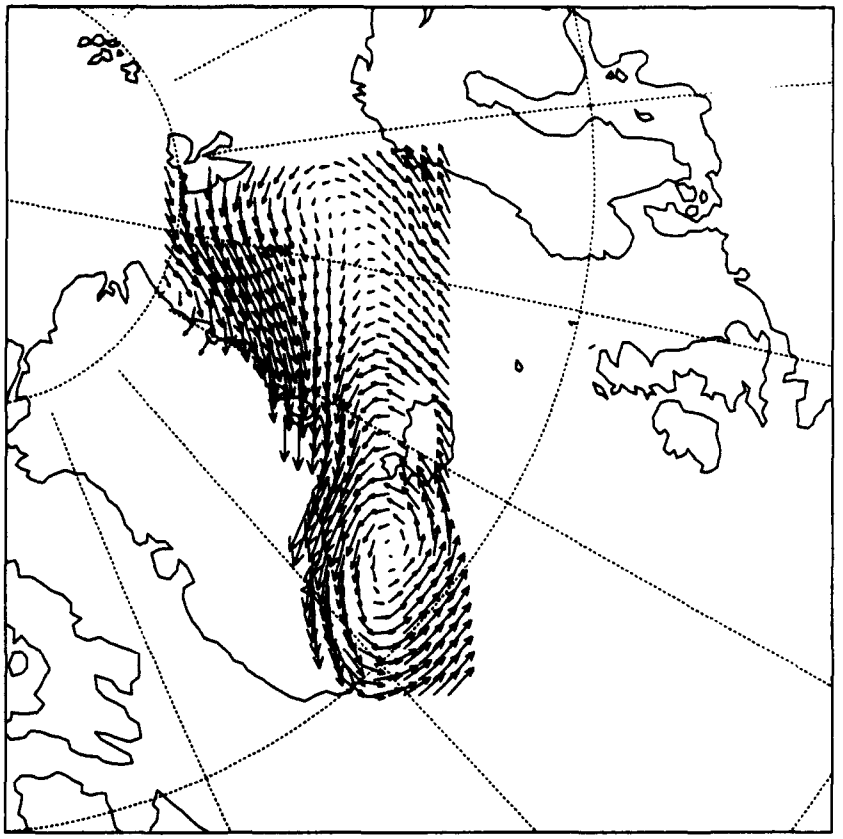


WIND VELOCITIES 1993 MARCH



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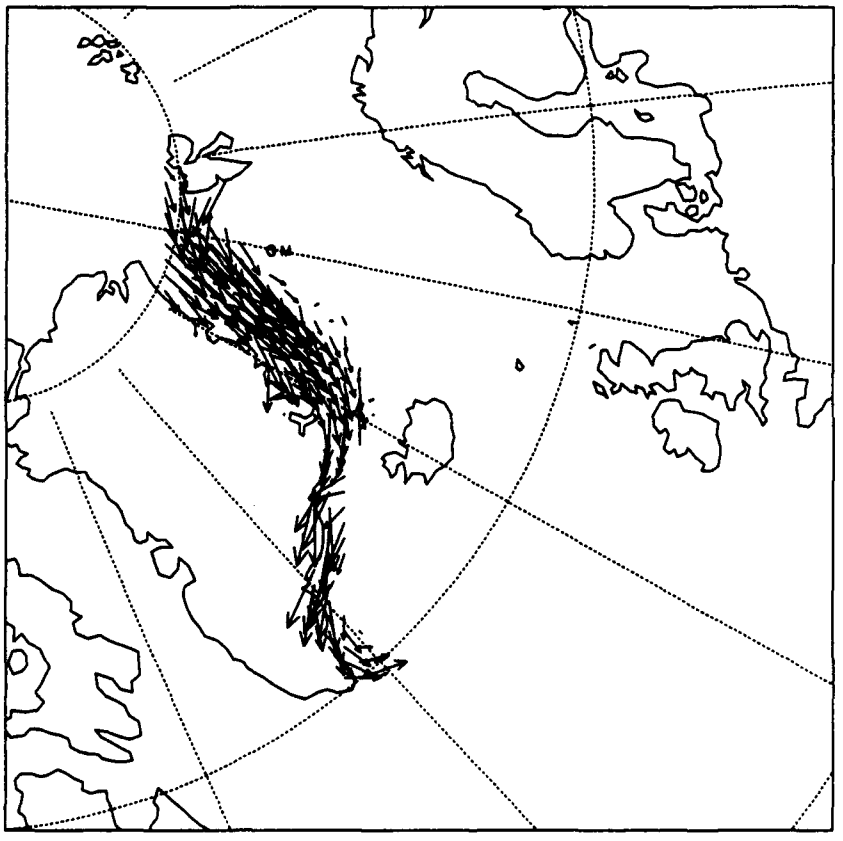

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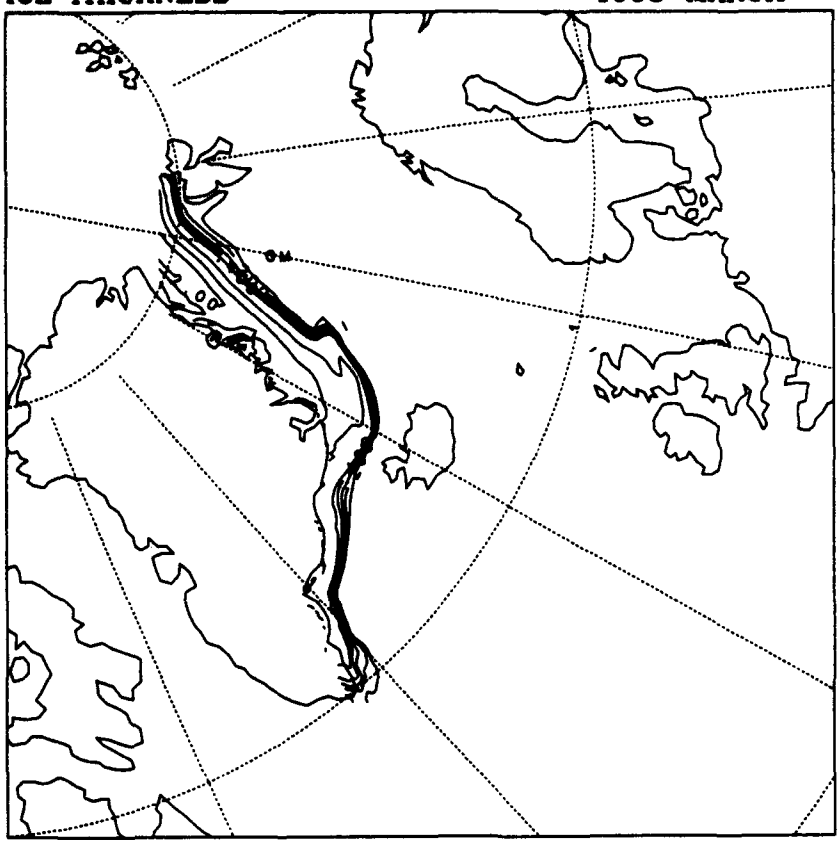

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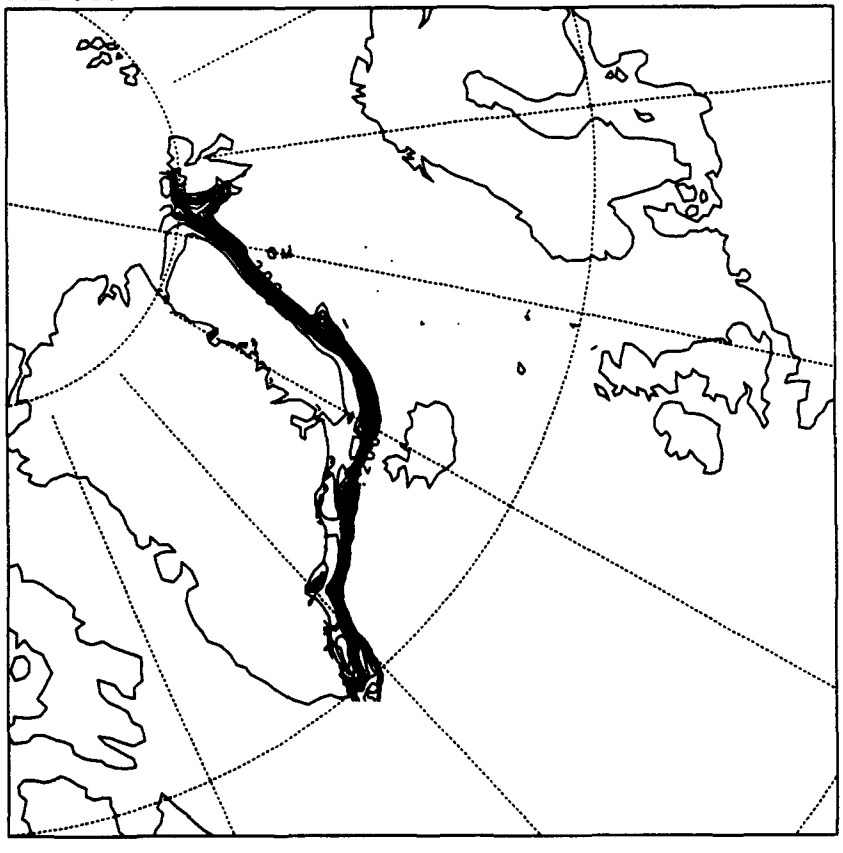
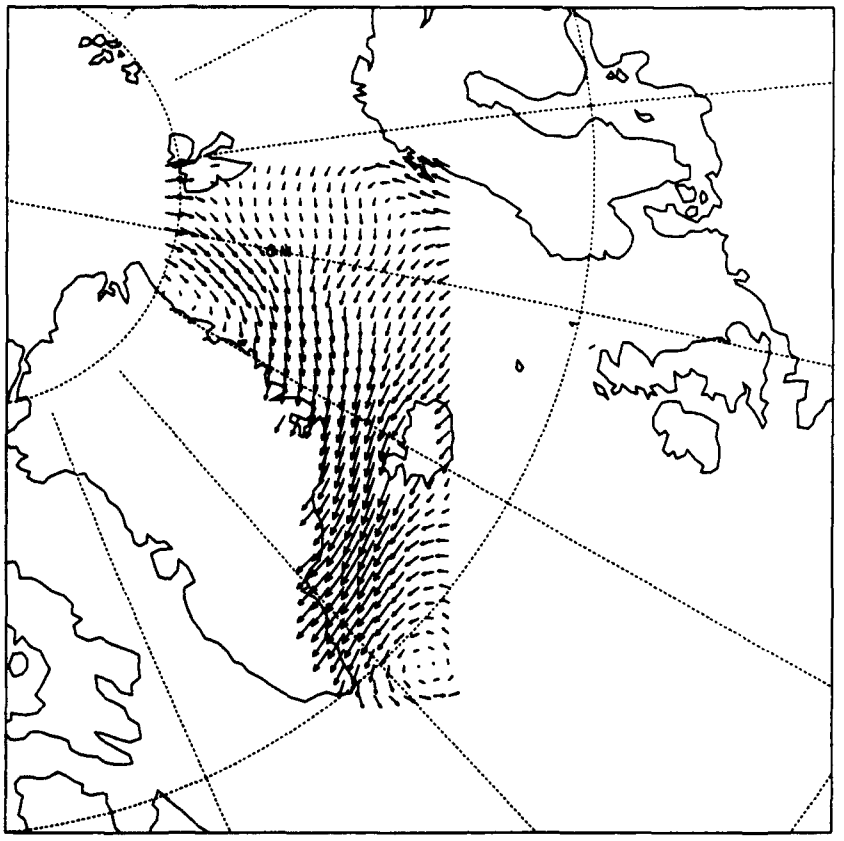
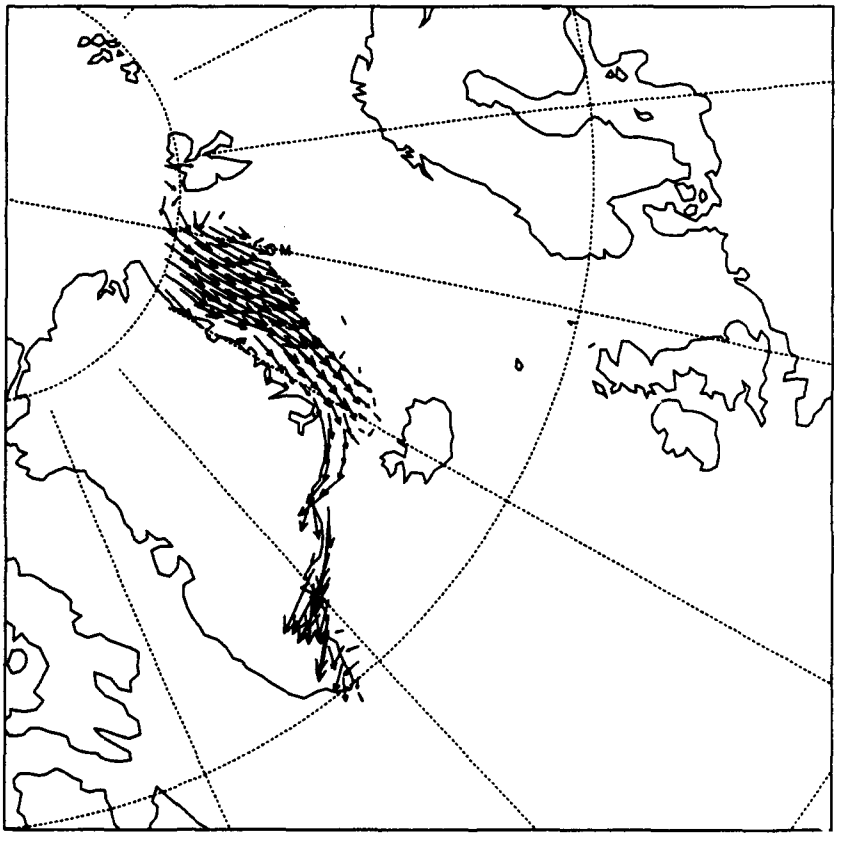


WIND VELOCITIES 1993 APRIL



0.300E+02
MAXIMUM VECTOR

ICE VELOCITIES 1993 APRIL



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MAXIMUM VECTOR

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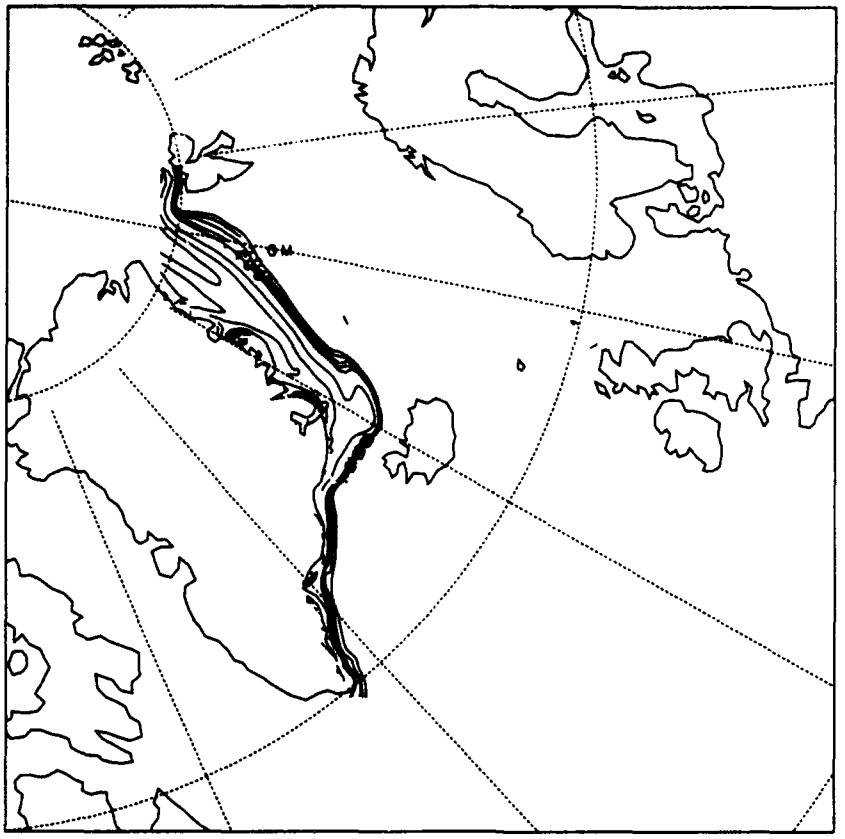

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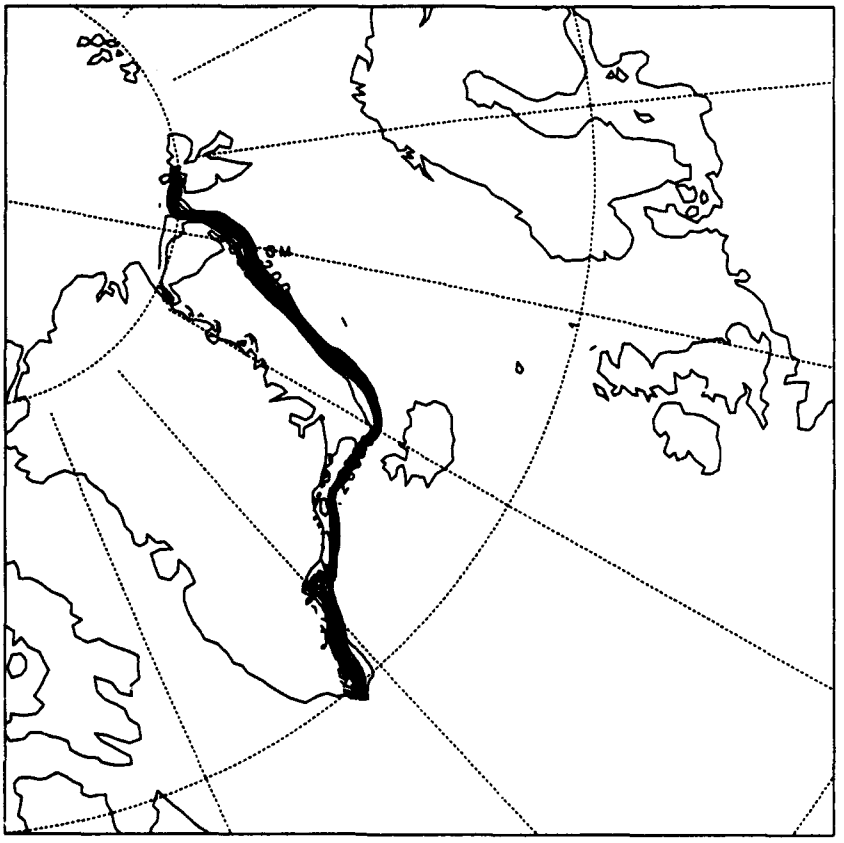

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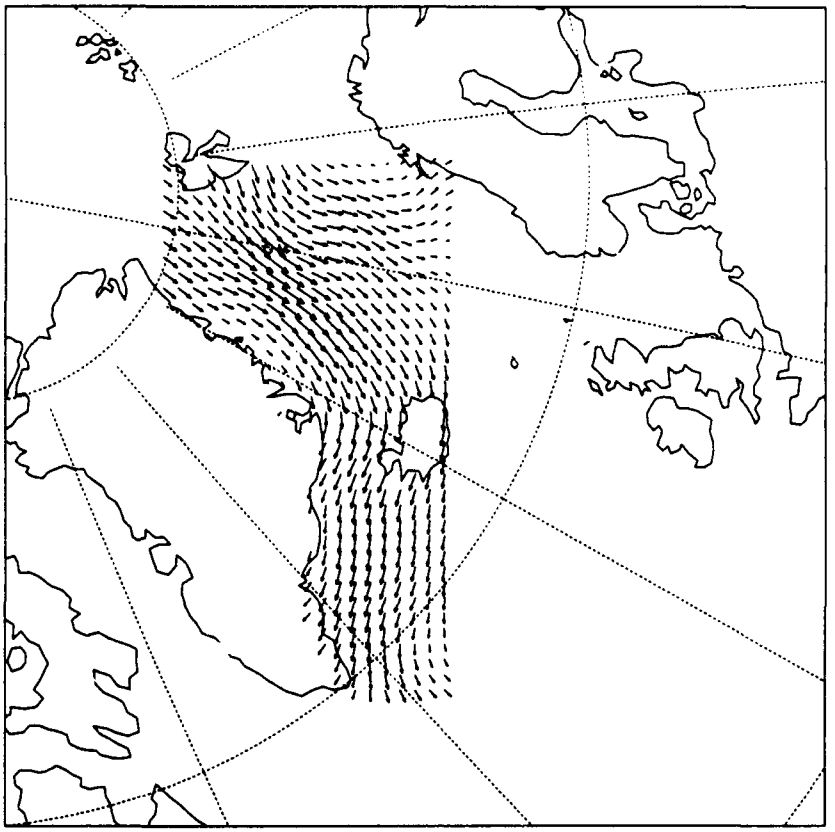

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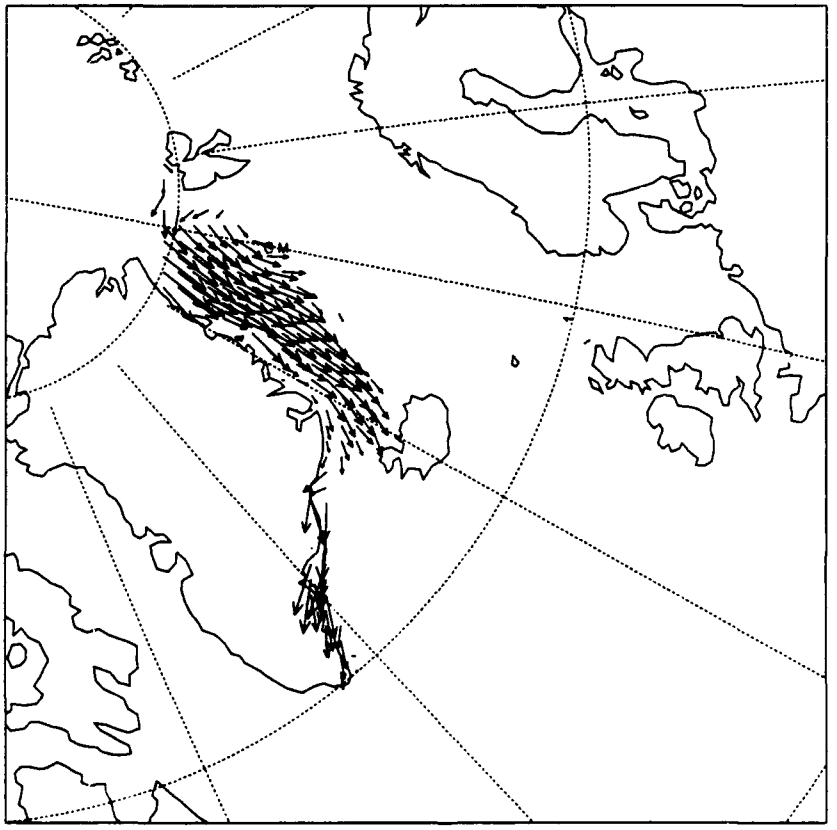

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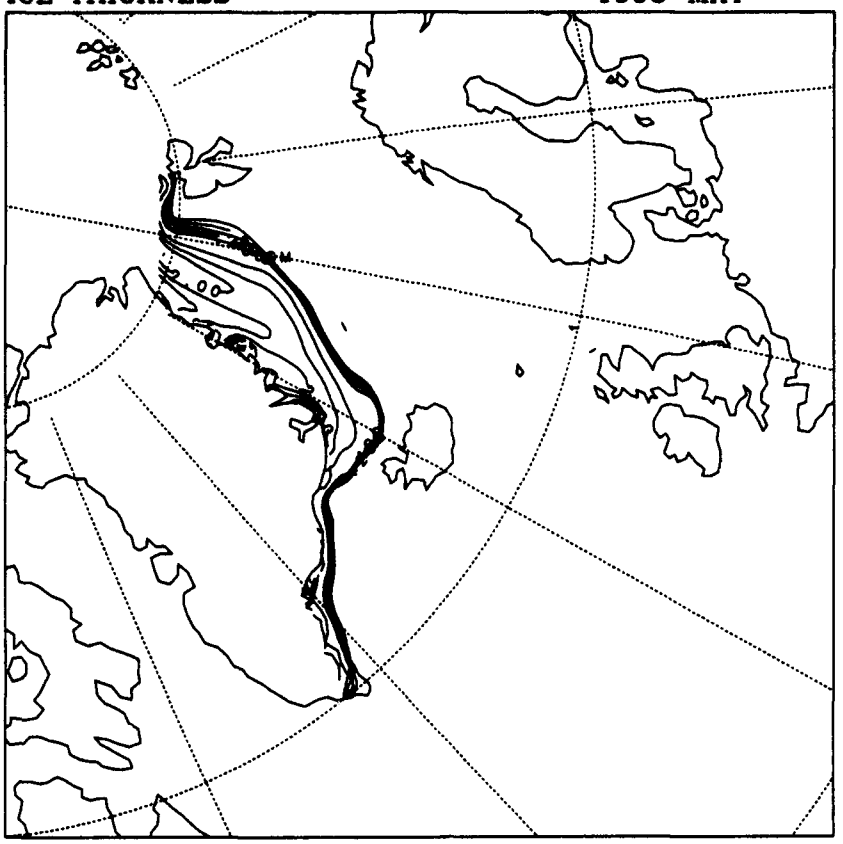

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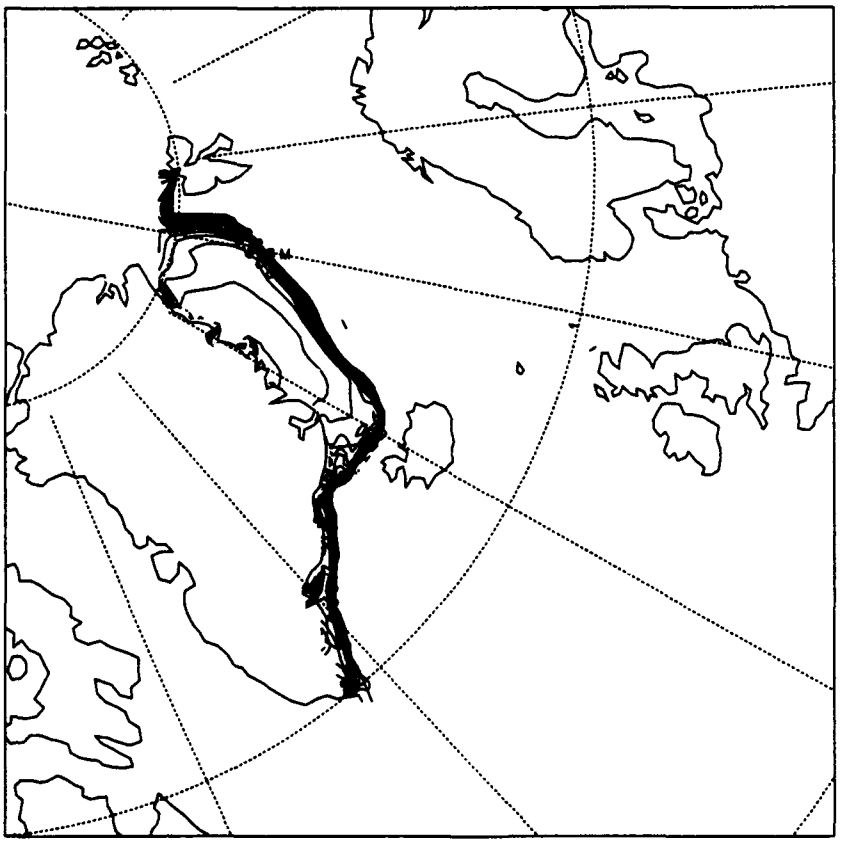
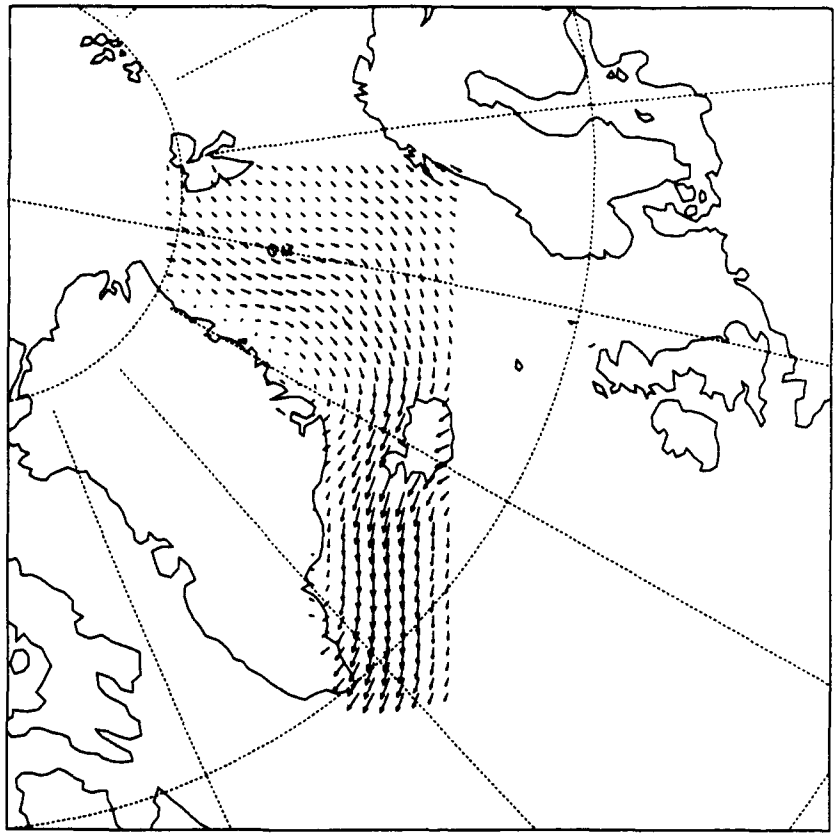


WIND VELOCITIES 1993 JUNE



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MAXIMUM VECTOR

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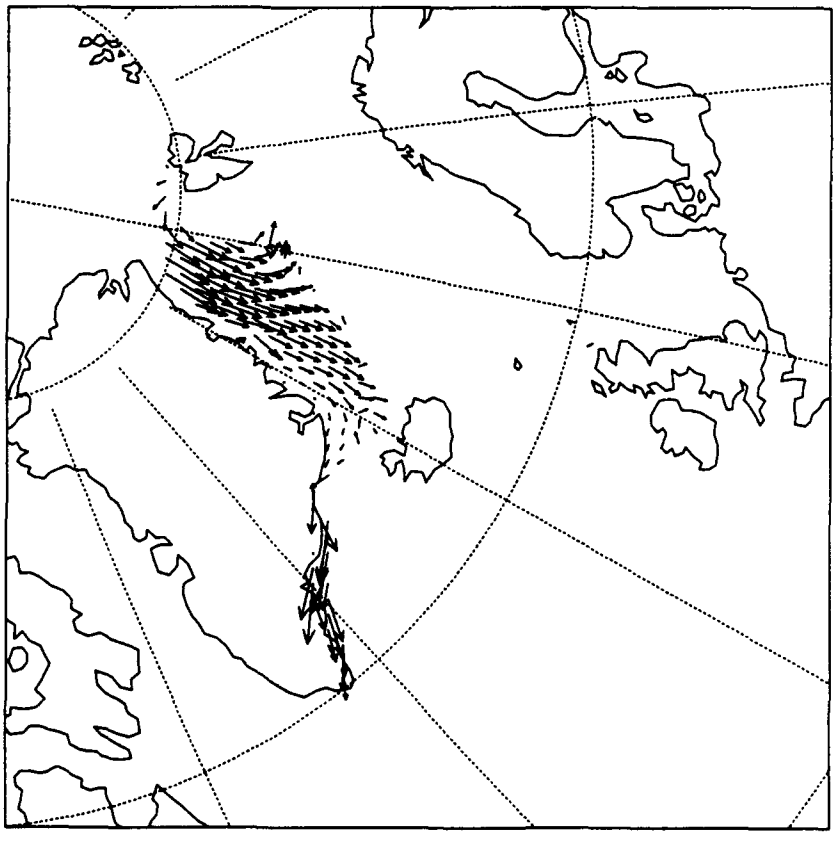

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MAXIMUM VECTOR

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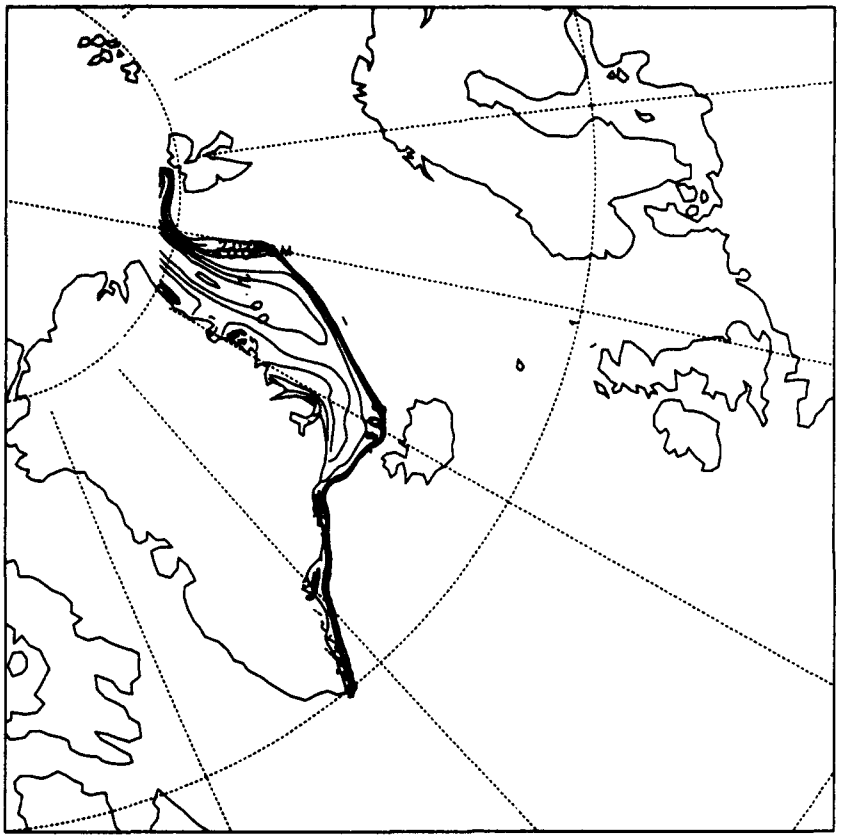

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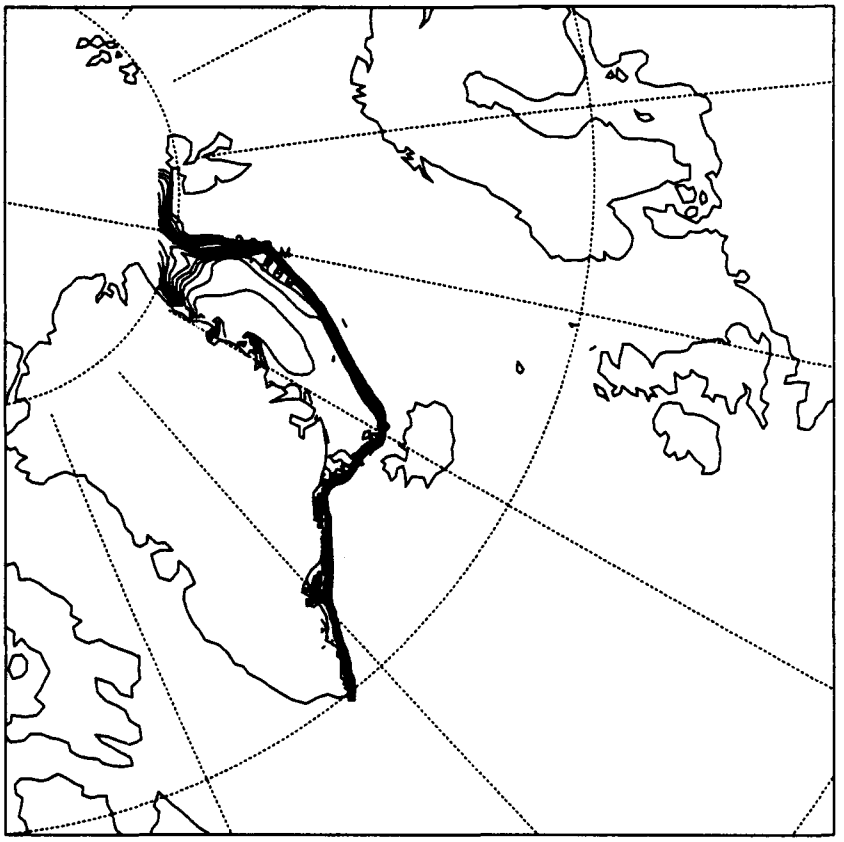
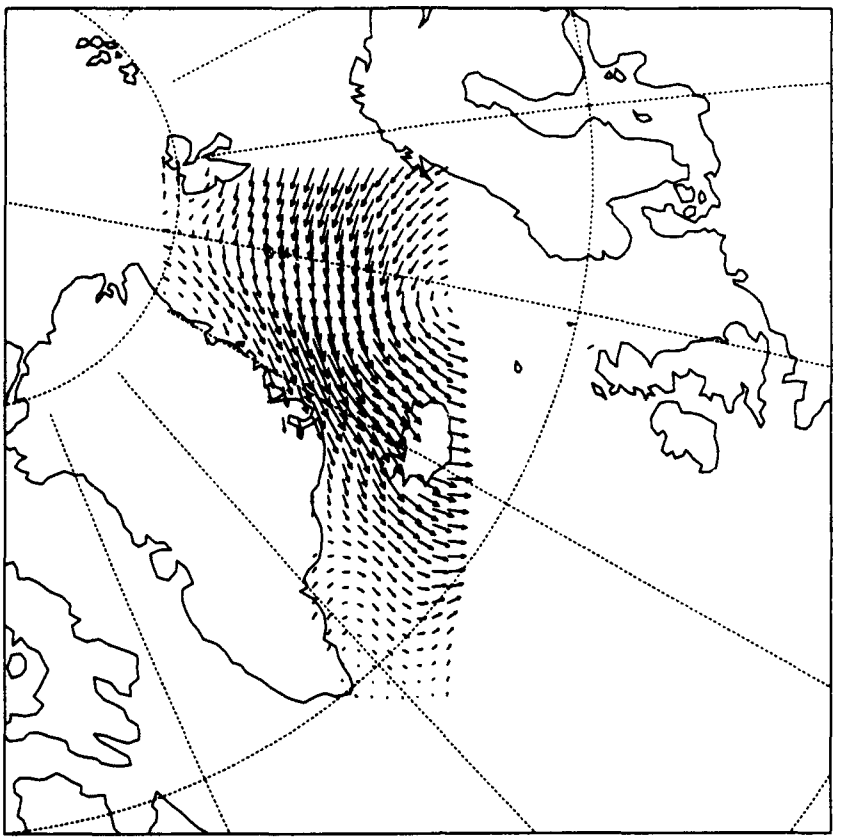


WIND VELOCITIES 1993 JULY



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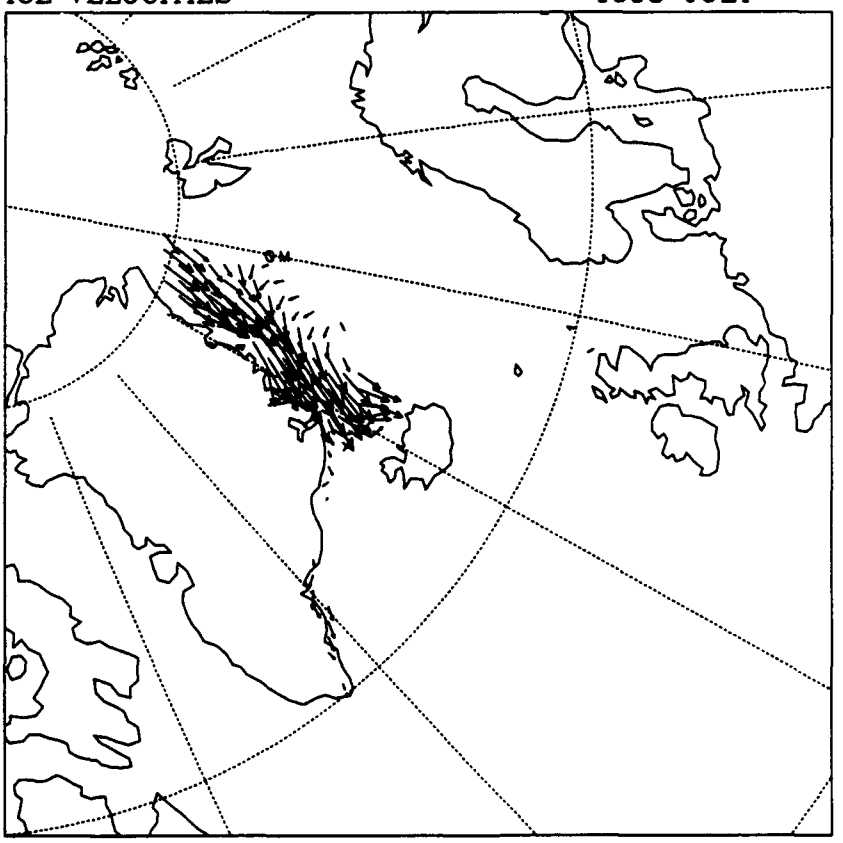

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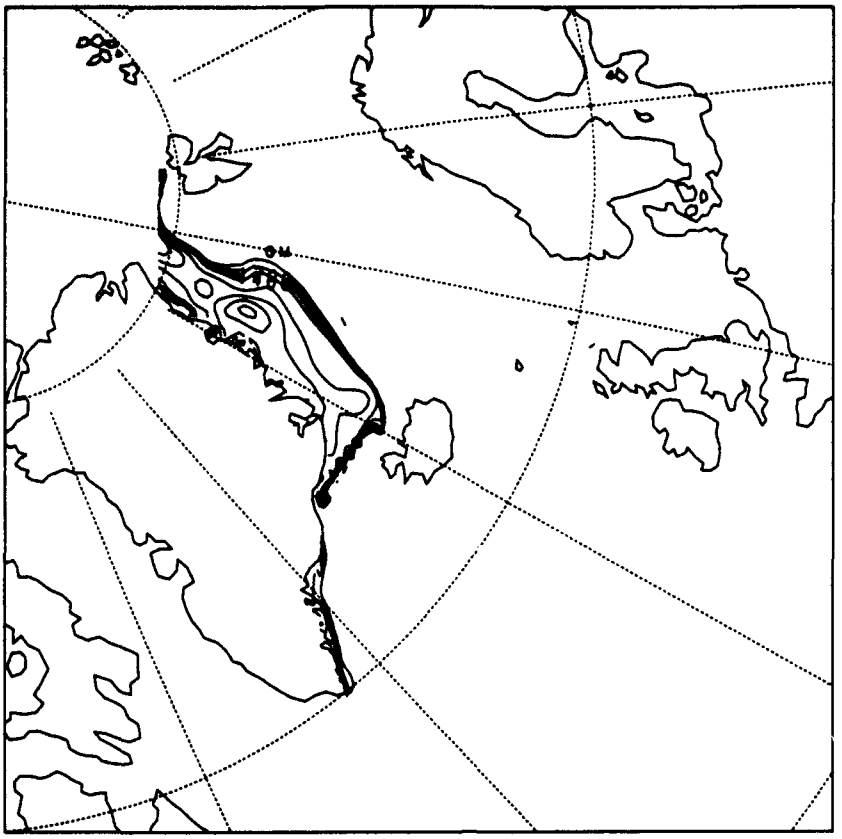
MAXIMUM VECTOR

ICE THICKNESS 1993 JULY



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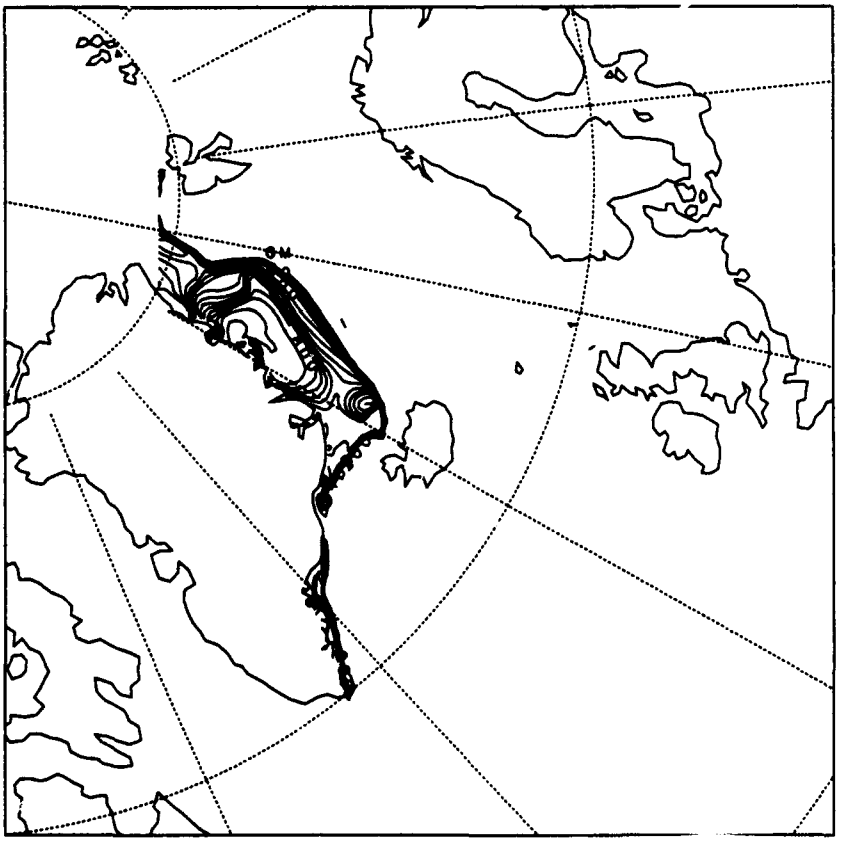
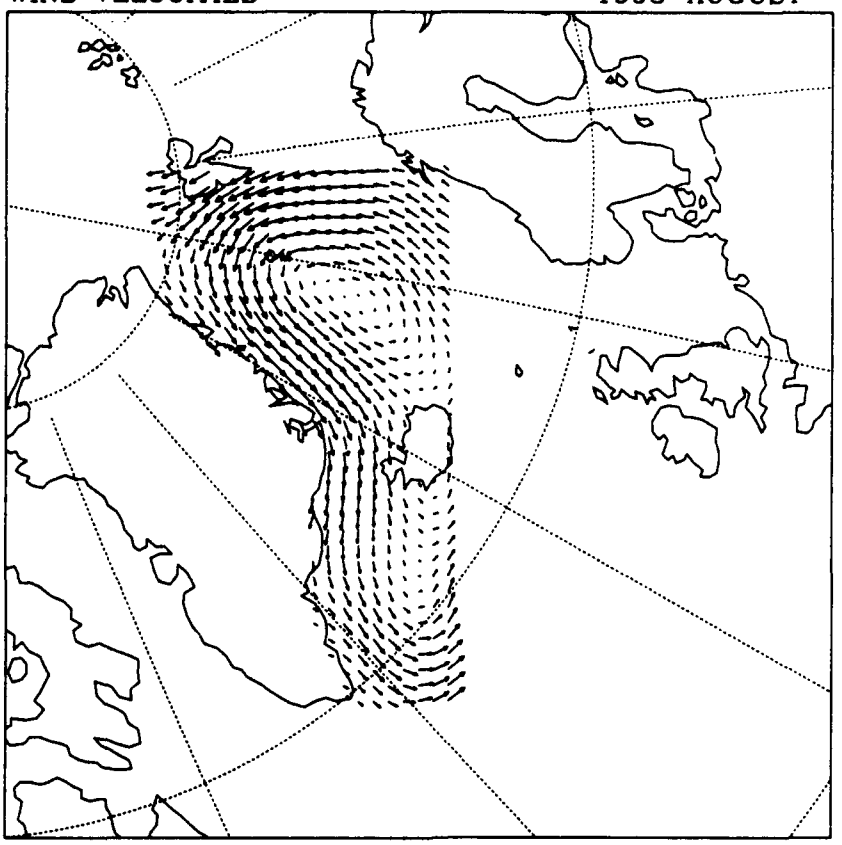


WIND VELOCITIES 1993 AUGUST



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MAXIMUM VECTOR

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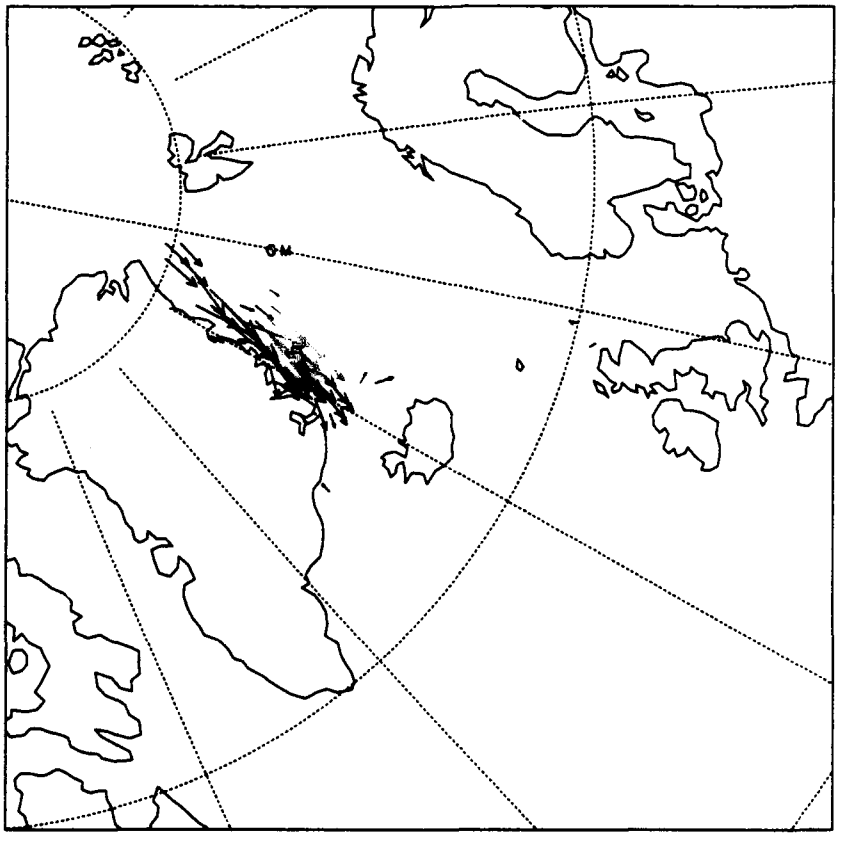

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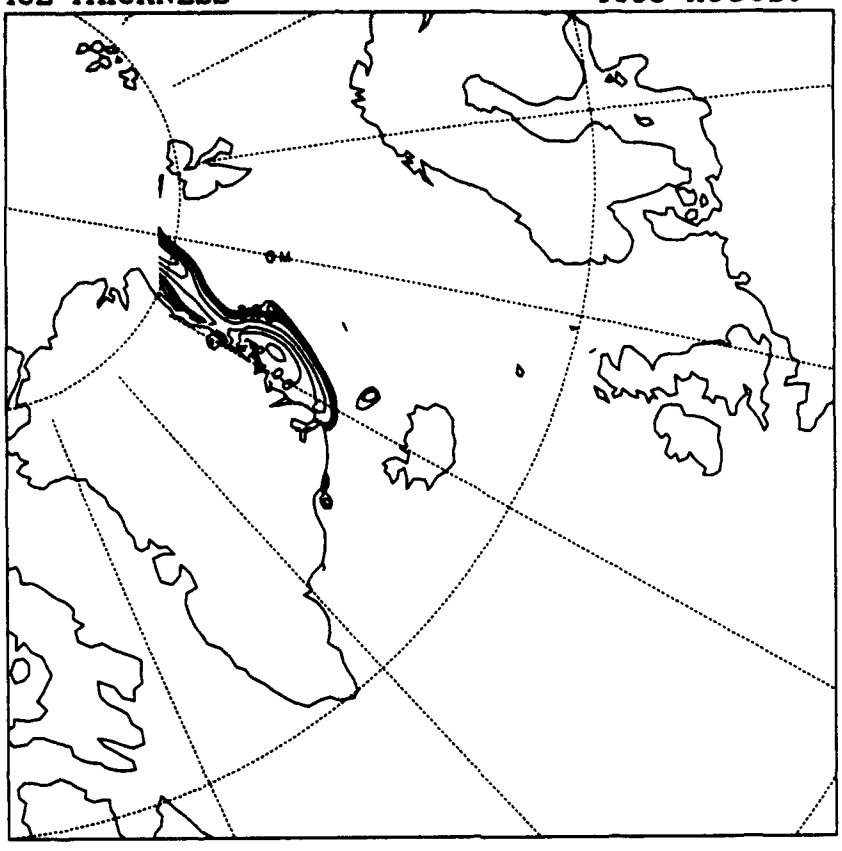
MAXIMUM VECTOR

ICE THICKNESS 1993 AUGUST



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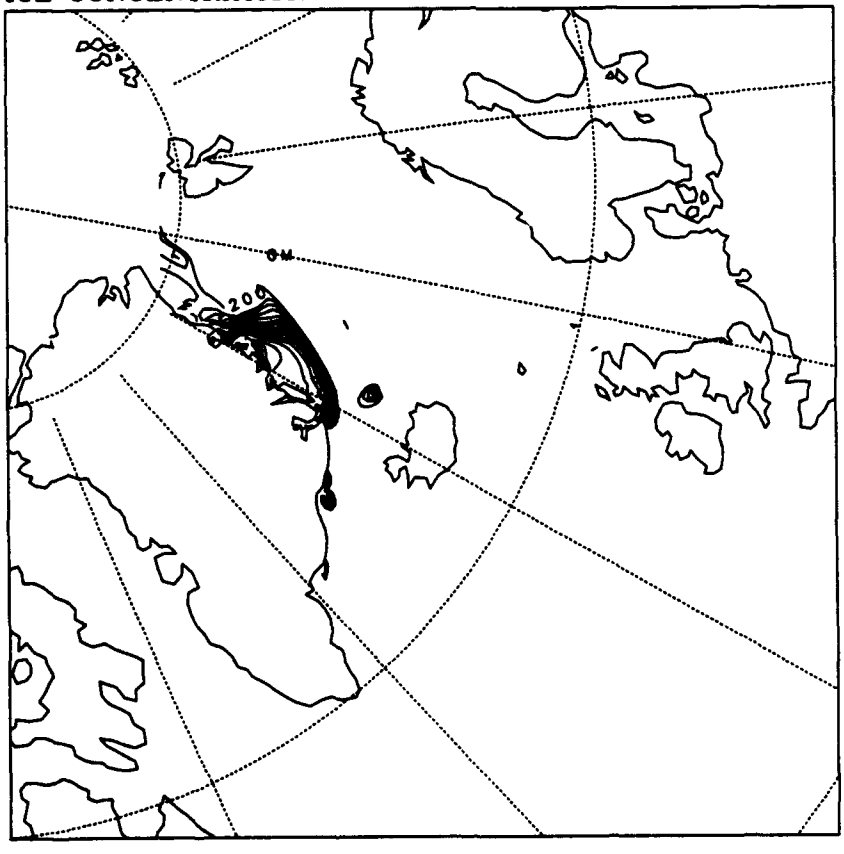
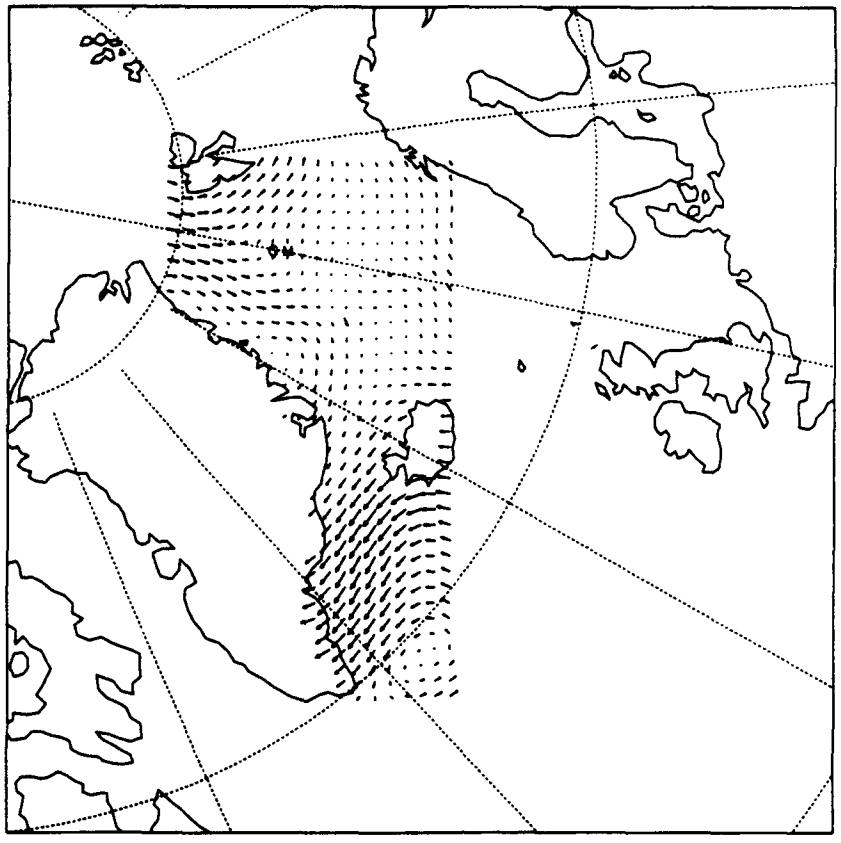


WIND VELOCITIES 1993 SEPTEMBER



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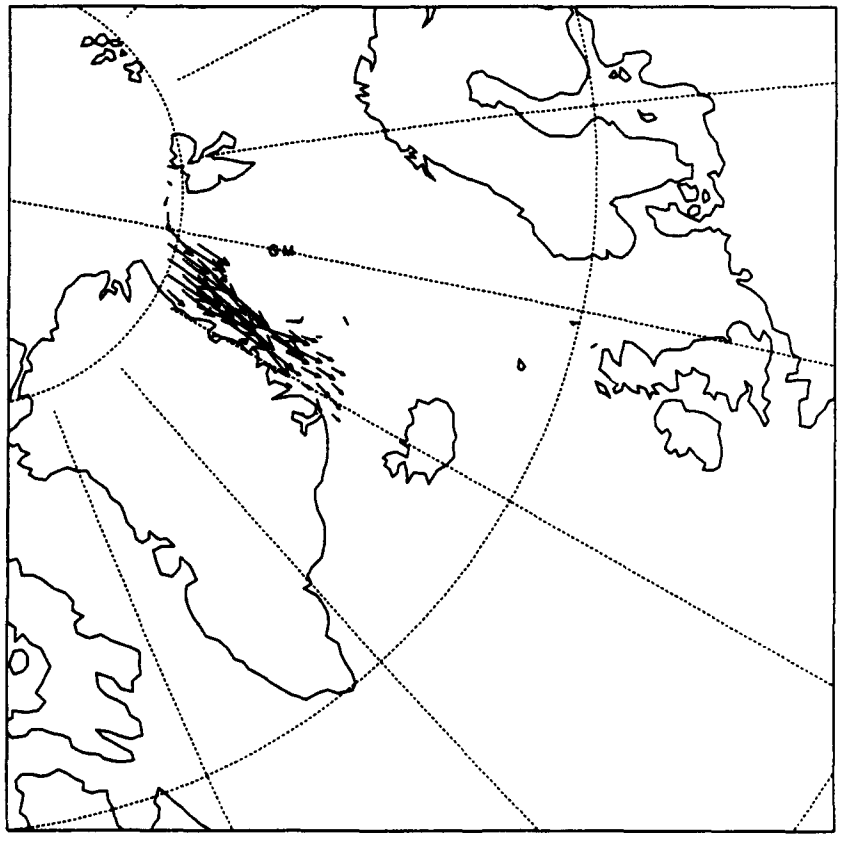
MAXIMUM VECTOR

ICE VELOCITIES 1993 SEPTEMBER



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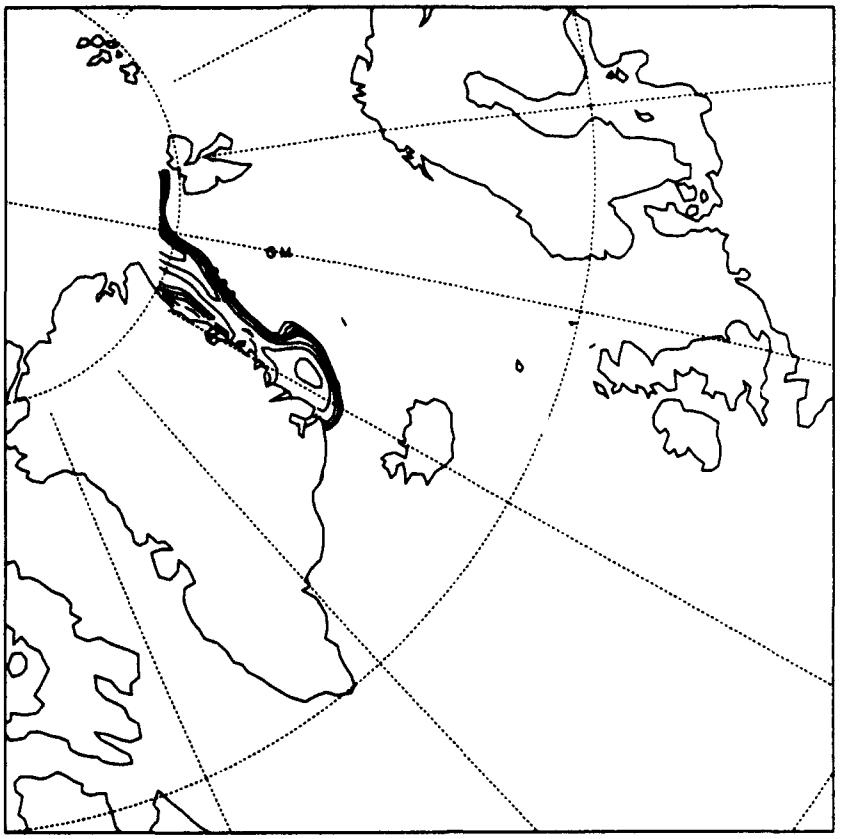
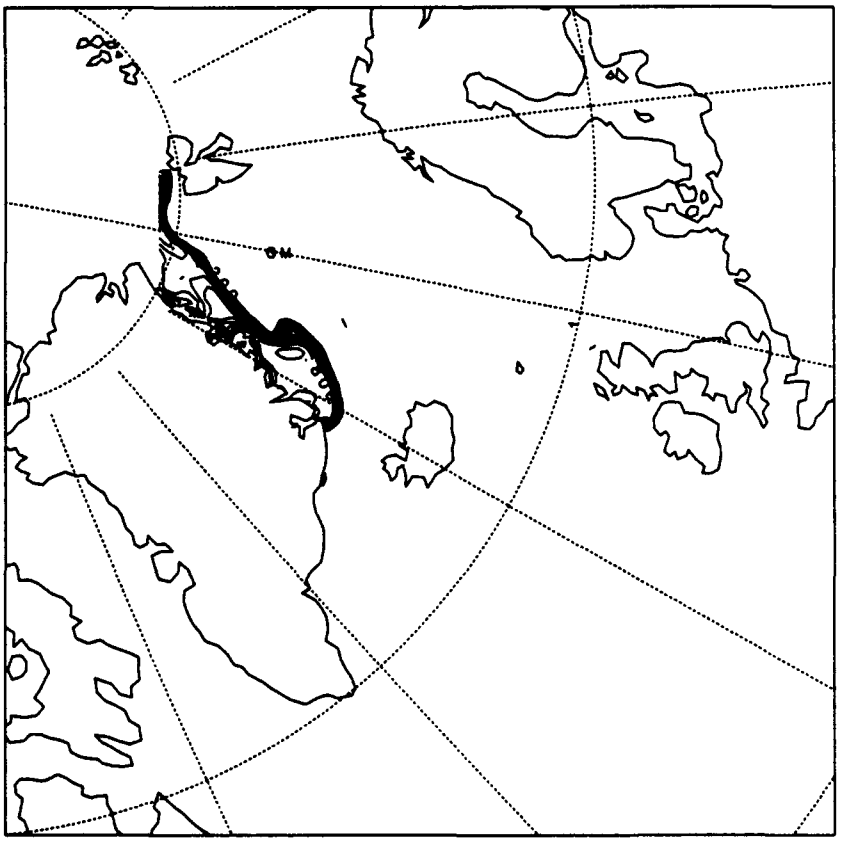
MAXIMUM VECTOR

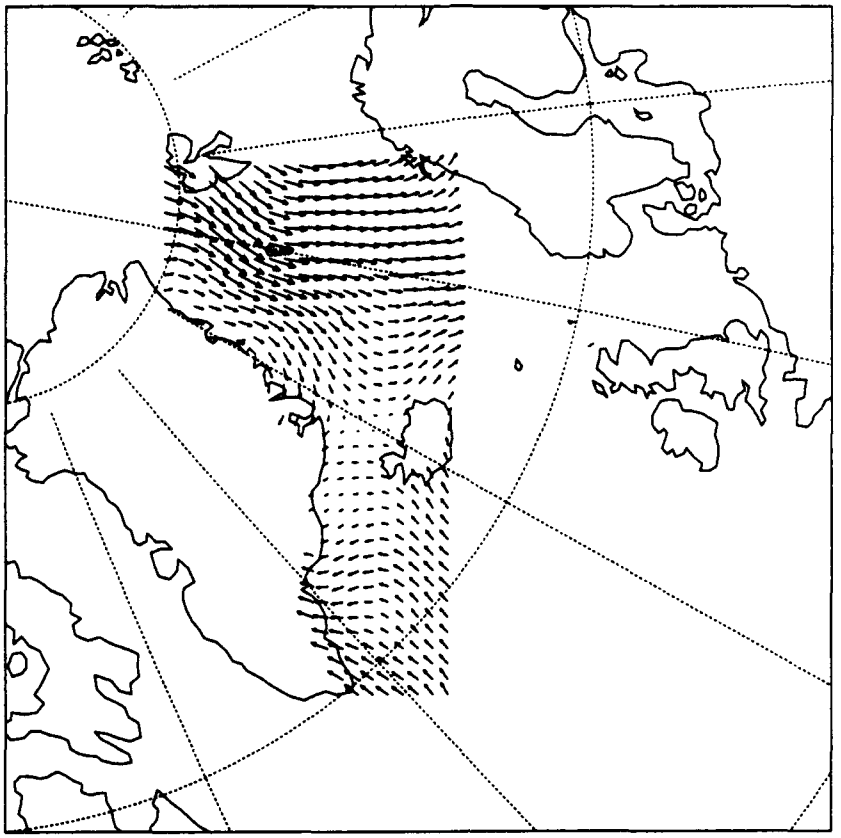
ICE THICKNESS 1993 SEPTEMBER



ICE CONCENTRATION 1993 SEPTEMBER



WIND VELOCITIES 1993 OCTOBER



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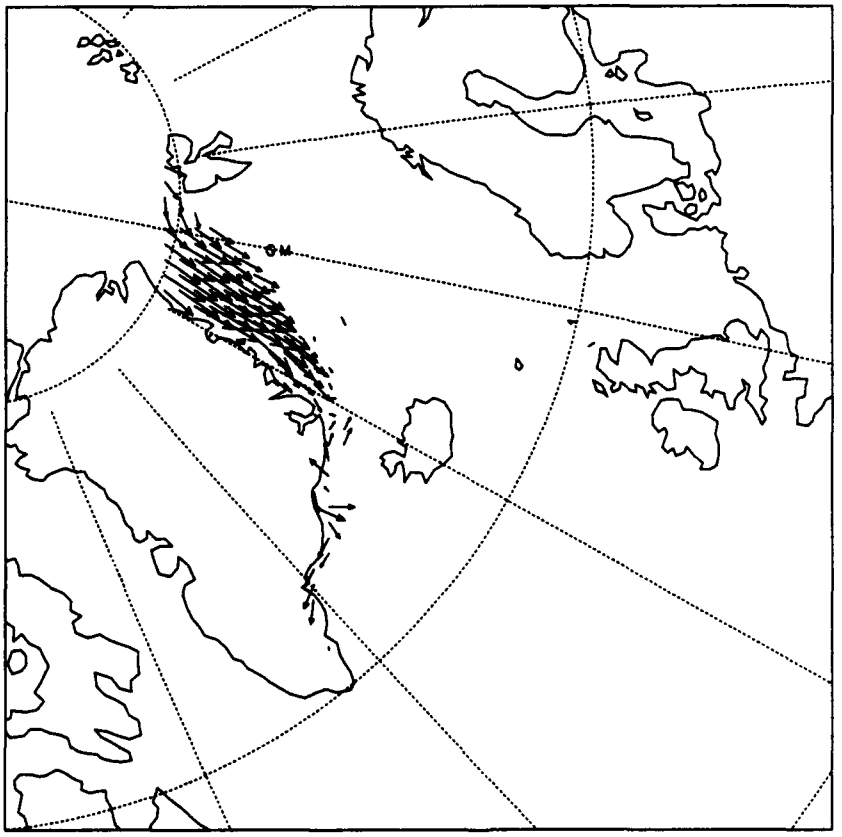
MAXIMUM VECTOR

ICE VELOCITIES 1993 OCTOBER



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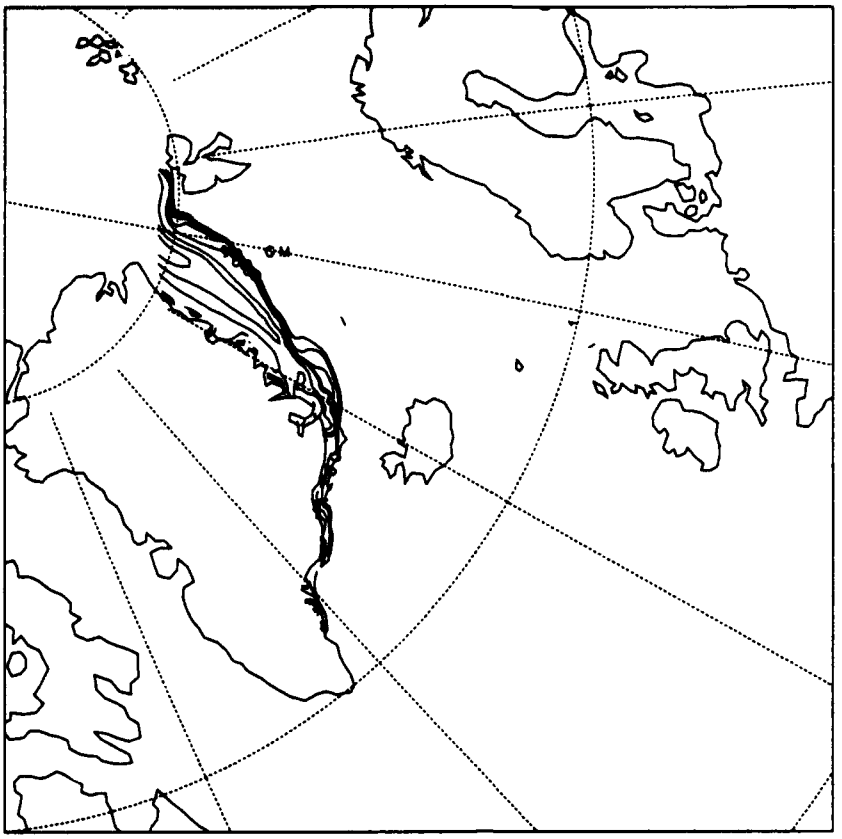
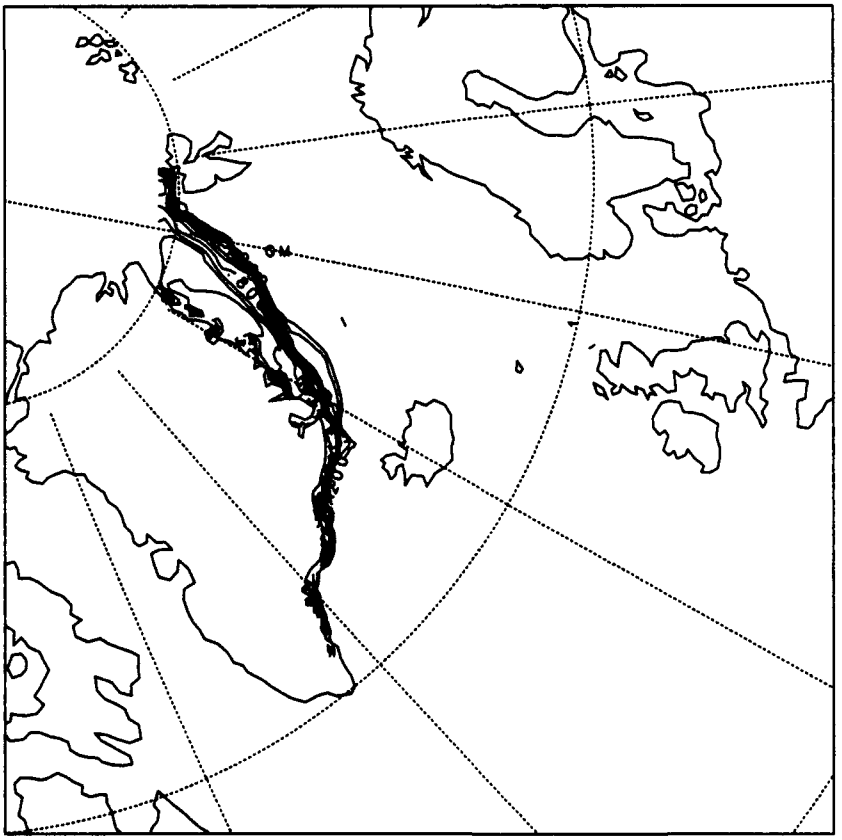
MAXIMUM VECTOR

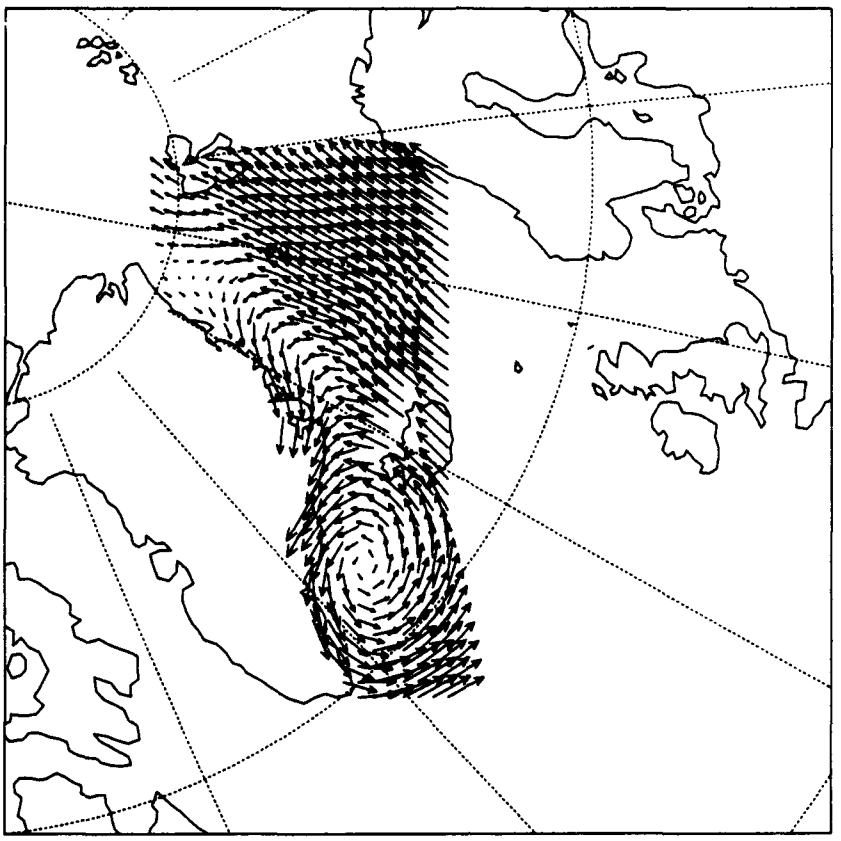
ICE THICKNESS 1993 OCTOBER



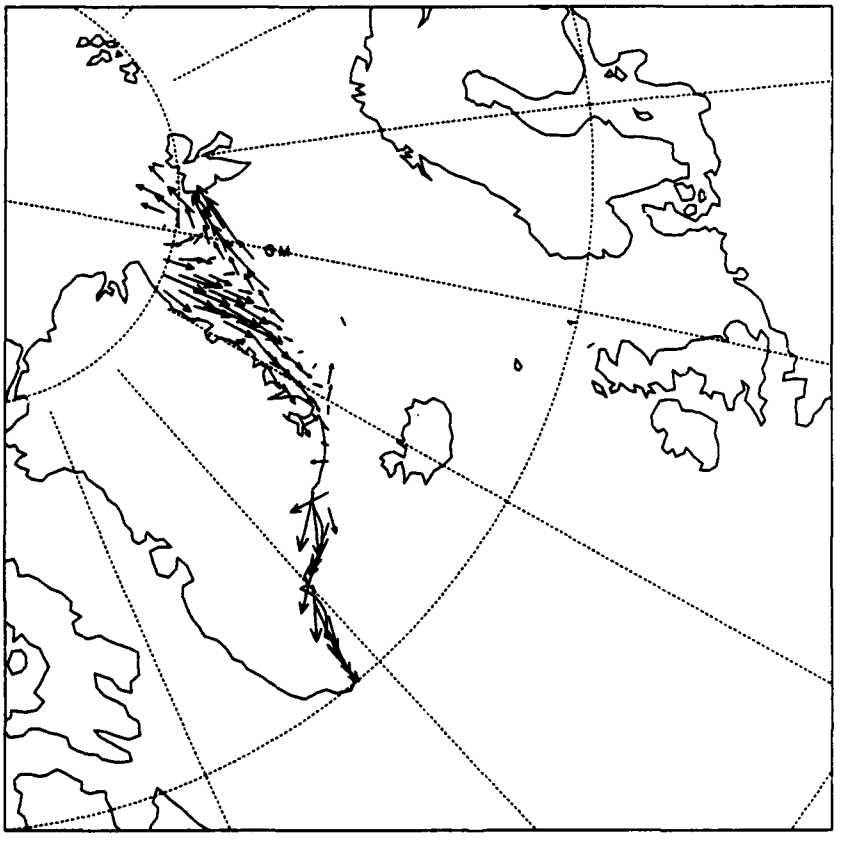
ICE CONCENTRATION 1993 OCTOBER



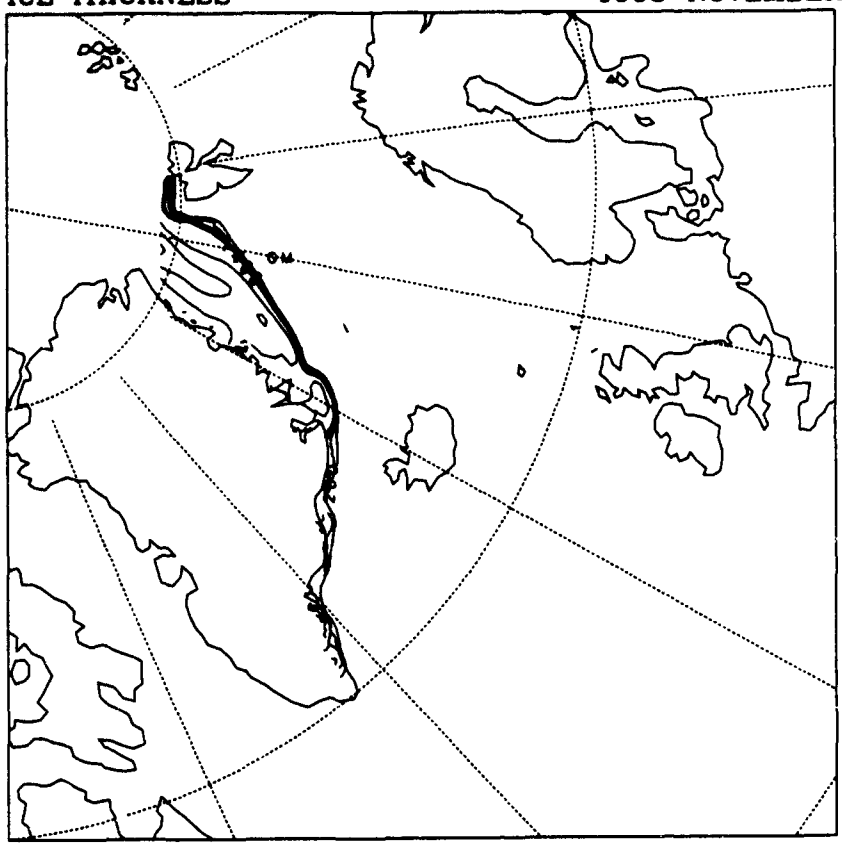
WIND VELOCITIES 1993 NOVEMBER



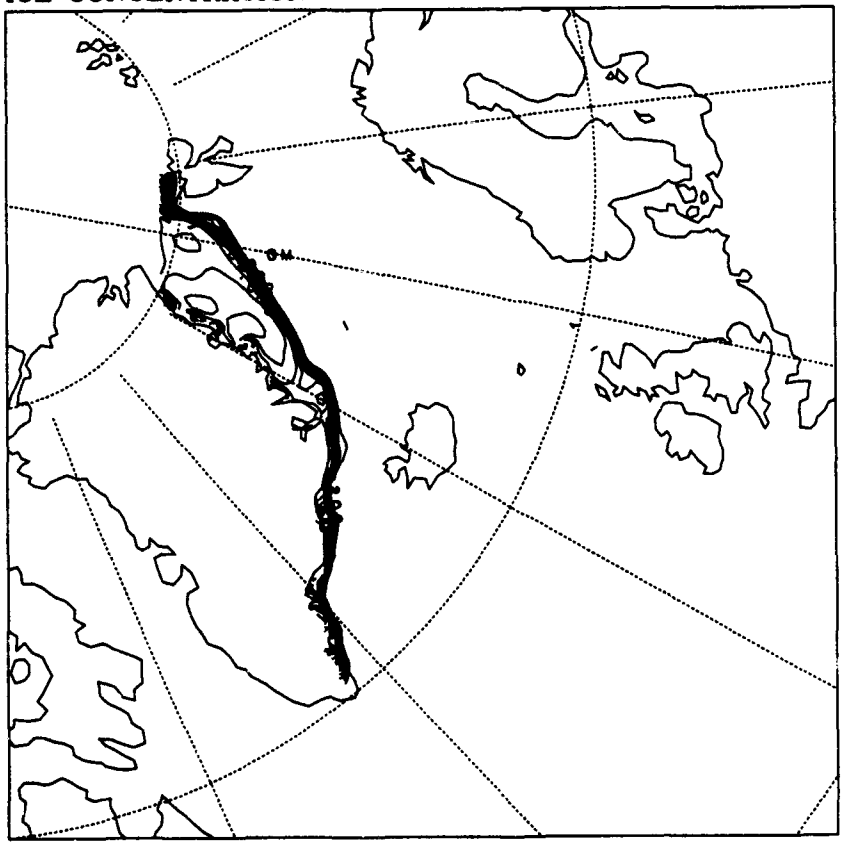
ICE VELOCITIES 1993 NOVEMBER



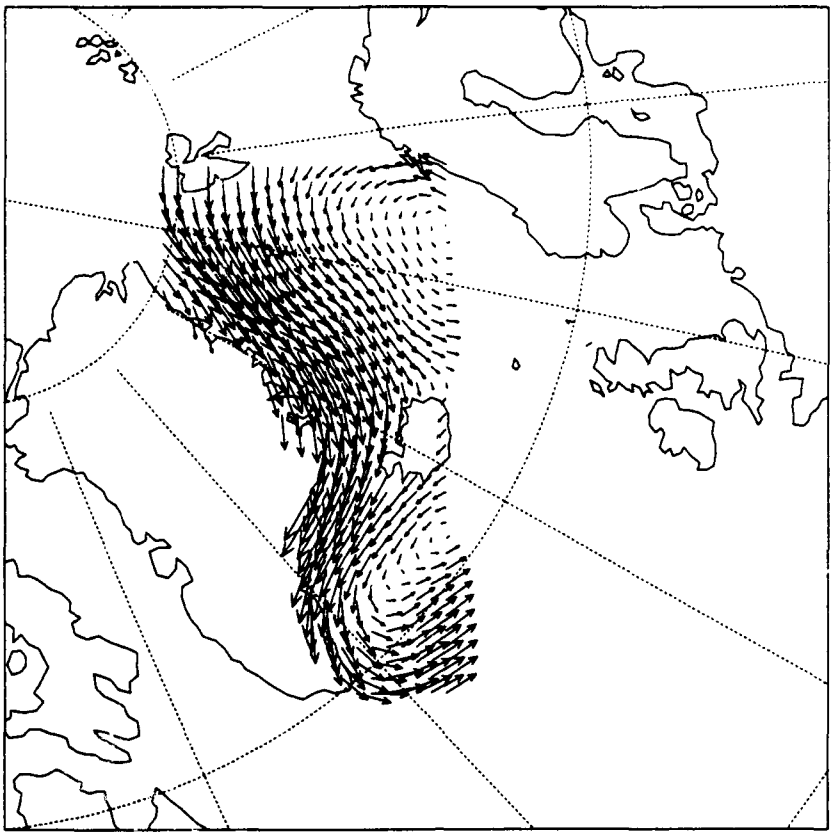
ICE THICKNESS 1993 NOVEMBER



ICE CONCENTRATION 1993 NOVEMBER



WIND VELOCITIES 1993 DECEMBER



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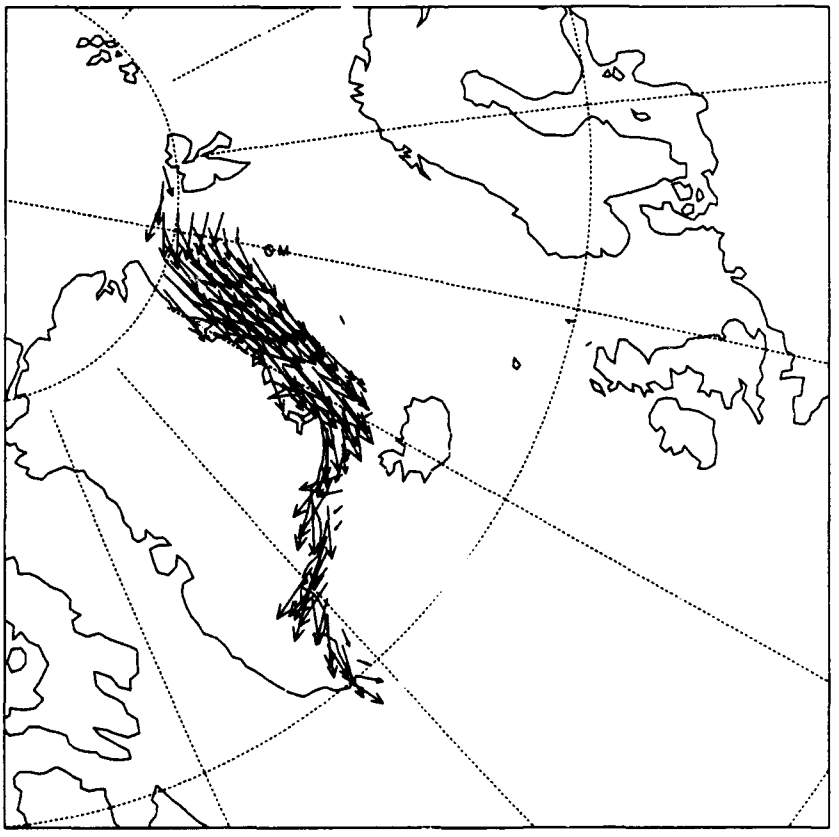
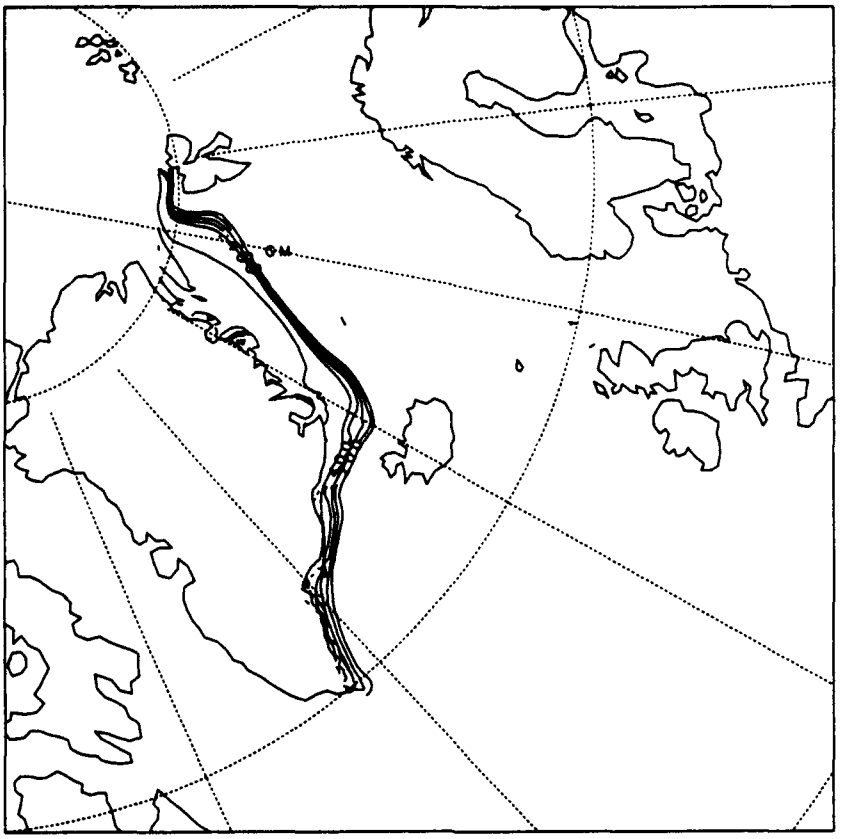


ICE THICKNESS 1993 DECEMBER



ICE CONCENTRATION 1993 DECEMBER